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THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE.

EDWARD C. PICKERING, DIRECTOR.

CIRCULARS

1 TO 50

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HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 1.

INTRODUCTION.

For some years the need has been felt at the Harvard College Observatory of some means of making a more prompt announcement of the results of its work. It is proposed therefore to issue a series of circulars, as required, to announce any matters of interest, such as discoveries made here, the results of recent observations, new plans of work, and gifts or bequests. It is not proposed to give these circulars a wide distribution, but rather to use them as a means of bringing new facts to the attention of the editors of astronomical and other periodicals, and thus secure the immediate publication of such portions, as would be of interest to the readers of these periodicals. The distribution will be made without charge to such persons as will be likely to use the results. Editors who have published extracts from the circulars and desire their continuance are requested to signify this by sending to this Observatory marked copies of the publications in which the extracts appear.

A NEW STAR IN CARINA.

From an examination of the Draper Memorial photographs taken at the Arequipa Station of the Observatory, Mrs. Fleming has discovered that a new star appeared in the constellation Carina in the spring of 1895. A photograph, B 13027, taken on April 14, 1895, with an exposure of 60 minutes, shows a peculiar spectrum in which the hydrogen lines $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and $H\zeta$ are bright, and the last four of these are accompanied by dark lines of slightly shorter wavelength. A conspicuous dark line also appears about midway between $H\gamma$ and $H\delta$. A comparison of the spectrum of this star with that of Nova Aurigae and Nova Normae shows that all three closely resemble each other and are apparently identical in their essential features. Another photograph taken on June 15 with an exposure of 60 minutes shows a change in the spectrum of this object. The hydrogen lines $H\beta$, $H\gamma$, and $H\delta$, are still bright although the continuous spectrum is very faint. Another line whose wavelength is about 4700 is here as bright as the hydrogen lines. On the photograph taken on April 14 it is barely visible.

An examination was next made of all the photographs of the region containing this star. On sixty-two plates, the first taken on May 17, 1889, and the last on March 5, 1895, no trace of the star is visible, although on some of them stars as faint as the fourteenth magnitude are clearly seen. The exposures of these plates varied from 10 to 242 minutes. On nine plates, the first taken on April 8 and the last on July 1, 1895, the star appears and its photographic brightness diminishes during that time from the eighth to the eleventh magnitude. This star precedes A. G. C. 15269 (photometric magnitude 5.47) $0^m.5$, and is $0'.7$ north. Its approximate position for 1900 is therefore in R. A. $11^h 3^m.9$, Dec. $-61^\circ 24'$. Two stars of the eleventh magnitude are near the Nova. One is nearly north, $110''$ distant, the other is $80''$ south preceding.

EDWARD C. PICKERING.

OCTOBER 30, 1895.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 2.

VARIABLE STAR CLUSTERS.

Professor Solon I. Bailey, in charge of the station at Arequipa, maintained by this Observatory, has discovered from an examination of the photographs obtained by him of certain globular clusters that they contain an extraordinary number of variable stars. This is not a general condition of stellar clusters, however, for in others similarly examined by Professor Bailey no variable stars have been found. The photographs used in this discussion were taken at Arequipa with the 13 inch Boyden Telescope. In the cluster in Canes Venatici, Messier 3 (N. G. C. 5272), no less than eighty-seven stars have been proved to be variable from an examination of fifteen photographic plates. The change in every case is certain, and has been confirmed independently by Mrs. Fleming and the writer from an examination of six of these plates. Sometimes the variation amounts to two magnitudes or more, and sometimes it does not exceed half a magnitude on the plates which were used for its confirmation. No star was included in this count if either of the three observers doubted the variation. Nine other stars were found to be variable by Mr. Bailey, but they are not included since they did not show sufficient change on the plates used in confirmation. In like manner, from an examination of seventeen plates, Mr. Bailey found forty-six variables in the cluster Messier 5 (N. G. C. 5904) which were confirmed on five plates. Fourteen other stars in this cluster are also probably variable but have not yet been confirmed. This cluster is frequently described as 5 M Librae, probably following Smyth. It is actually in Serpens, and very near 5 Serpentis. Two variable stars have been confirmed in N. G. C. 7089 from an examination of six plates, three in N. G. C. 7099 from five plates, five with small range in N. G. C. 362 from three plates, and four in N. G. C. 6656 from three plates. On the other hand, a similar examination of two plates of each of the clusters N. G. C. 6218, 6397, 6626, 6705, and 6752 failed to detect a single variable star, several hundred stars in each case apparently having exactly the same brightness on both

plates. As, however, these plates were taken within a few days of each other, only variable stars of short period could have been detected on them. In general, no variables have been found within about one minute of the centre of the clusters on account of the closeness of the stars. None of these variables are more than ten minutes distant from the centres of the clusters. In N. G. C. 5904 a circle 110" in diameter contains sixteen stars, six of which, or nearly forty per cent, are variable. In the entire cluster about 750 stars were examined and 46 found to be variable, as above stated, so that they form about six per cent of the whole. Of all the stars visible to the naked eye less than one per cent are variable.

In 1890 Mr. Packer discovered two variable stars in the cluster N. G. C. 5904. (*English Mechanic*, Vol. LI, 378, *Sidereal Messenger* IX, 380, 381; X, 107.) One of these variables was discovered independently by Mr. Bailey but is not included in the above lists. Several stars in this cluster were thought to be variable by Mr. Common (*Monthly Notices*, L, 517; LI, 226). One of them is too near the centre, the others too distant to be included in the above discussion. The variable star discovered in the cluster N. G. C. 5272 by the writer in 1889 is also too near the centre to be included.

Some of these variable stars have short periods, not more than a few hours. For instance, one of them, No. 12, which precedes the centre of N. G. C. 5904 by about three minutes of arc. Five photographs of this cluster were taken on July 1, 1895, at intervals of an hour. The corresponding magnitudes of the variable as derived from these plates are 14.3, 13.5, 13.8, 13.9, and 14.3. Four plates taken on August 9, 1895, also at intervals of an hour gave the magnitudes 14.2, 14.6, 14.8 and 15.0.

Right ascensions and declinations cannot conveniently be used for indicating the individual stars in close clusters. They can only be found readily from photographic or other charts on which they are marked. Such charts are now being prepared for publication in the *Annals of the Observatory*. Meanwhile marked photographs will be sent to such astronomers as may wish to study them.

EDWARD C. PICKERING.

NOVEMBER 2, 1895.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 3.

NEW VARIABLE STAR OF THE ALGOL TYPE.

The star B. D. + 17° 4367, magn. 9.1, whose approximate position for 1900 is in R. A. 20^h 33^m.1, Dec. + 17° 56', appears to be a variable star of the Algol type. On July 18, 1895, Miss Louisa D. Wells found that no trace of this star appeared on the photograph I 4359, taken with the 8 inch Draper telescope on September 26, 1891, exposure 16 m. On 71 other plates taken from June 30, 1890 to October 5, 1895, the star appears of its normal brightness. On December 12, 1895, at 10^h 42^m Greenwich Mean Time, Professor Arthur Searle, who had watched this star on several nights, found it more than a magnitude fainter than usual. During the next half hour it diminished about half a magnitude more. Meanwhile, a photograph taken with the 8 inch Draper telescope, I 14036, confirmed the diminution in light. Unfortunately, at 11^h 15^m G. M. T., clouds covered the region, and the star, although carefully looked for, was not seen again that evening. The change in brightness appears to be rapid and the range of variation to be large, exceeding two magnitudes. The nearest bright star is B. D. + 17° 4370, magn. 7.0, which follows 14" and is south 1'. The variability of B. D. + 17° 4370 has been suspected by Espin (*English Mechanic*, Vol. LXII, 334) and also independently by Mrs. Fleming in 1890.

EDWARD C. PICKERING.

DECEMBER 13, 1895.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 4.

A NEW STAR IN CENTAURUS.

A new star in the constellation Centaurus was found by Mrs. Fleming on December 12, 1895, from an examination of the Draper Memorial photographs. Its approximate position for 1900 is in R. A. $13^h 34^m.3$, Dec.— $31^{\circ} 8'$. Attention was called to it from the peculiarity of the spectrum on Plate B 14151, taken at Arequipa on July 18, 1895, with the Bache Telescope, exposure 52 m. The spectrum resembles that of the nebula surrounding 30 Doradus, and also that of the star A. G. C. 20937, and is unlike that of an ordinary nebula or of the new stars in Auriga, Norma, and Carina. This object is very near the nebula N. G. C. 5253, which follows $1^{\circ} 28'$, and is north $23''$. No trace of it can be found on 55 plates taken from May 21, 1889, to June 14, 1895 inclusive. On July 8, 1895, it appeared on a chart plate, B 13965, and its magnitude was 7.2. On Plate B 10472 taken July 10, 1895, its magnitude was also 7.2. On December 16, 1895, a faint photographic image of it, magnitude 10.9, was obtained with the 11 inch Draper Telescope, although it was very low, faint, and near the sun. On this date, and on December 19, it was also seen by Mr. O. C. Wendell with the 15 inch Equatorial as a star of about the eleventh magnitude. An examination with a prism showed that the spectrum was monochromatic, and closely resembled that of the adjacent nebula. Although the spectrum is unlike those of the new stars in Auriga, Norma, and Carina, yet this object is like them in other respects. All were very faint or invisible for several years preceding their first known appearance. They suddenly attained their full brightness and soon began to fade. Like the new stars in Cygnus, Auriga, and Norma, this star appears to have changed into a gaseous nebula.

The star which was photographed in 1887 in the constellation Perseus apparently belongs to the same class. Its approximate position for 1900 was in R. A. $1^h 55^m.1$, Dec. $+ 56^{\circ} 15'$. Eight images of it were obtained on the Draper Memorial photographs in 1887, all in exactly the same place. Its photographic spectrum showed the hydrogen lines $H\beta$, $H\gamma$, $H\epsilon$, and a line near 4060, bright, and from this property it was discovered by Mrs. Fleming and assumed to be an ordinary variable star of long period. The spectrum is so faint that it is impossible to decide from it



whether it should be regarded as a new star of the class of Nova Aurigae, or as a variable star of long period like α Ceti, as the hydrogen lines are bright in both these classes of objects. This star soon faded away and does not appear on 81 photographs taken during the last eight years. It has also been repeatedly looked for in the sky without success. No trace of this star appears on two photographs taken November 3, 1885, and December 21, 1886.

A list of the new stars hitherto discovered is given in the annexed table. Some changes would occur in it, if changes were made in the definition assumed for this class of objects. Early observations of several objects frequently called new stars, but which may have been comets, and whose positions are uncertain, have not been included. The stars T Bootis and U Scorpii have not been included, although they also may be new stars, as only one appearance of each has been noted. The name of the constellation is followed by the right ascension and declination for 1900, and the greatest brightness. The year of appearance is followed by the name of the discoverer; or, in the case of the earlier stars, of the principal observer.

NEW STARS.

CONSTELLATION.	R. A. 1900.		DEC. 1900.		MAGN.	YEAR.	DISCOVERER.
	<i>h</i>	<i>m</i>	<i>h</i>	<i>m</i>			
Cassiopeia	0	19.2	+ 63	36	— 5?	1572	Tycho Brahe
Cygnus	20	14.1	+ 37	43	3	1600	Janson
Ophiuchus	17	24.6	— 21	24	— 4?	1604	Kepler
Vulpecula	19	43.5	+ 27	4	3	1670	Anthelm
Ophiuchus	16	53.9	— 12	44	5	1848	Hind
Scorpius	16	11.1	— 22	44	7	1860	Auwers
Corona Borealis	15	55.3	+ 26	12	2	1866	Birmingham
Cygnus	21	37.8	+ 42	23	3	1876	Schmidt
Andromeda	0	37.2	+ 40	43	7	1885	Hartwig
Persens	1	55.1	+ 56	15	9	1887	Fleming
Auriga	5	25.6	+ 30	22	4	1891	Anderson
Norma	15	22.2	— 50	11	7	1893	Fleming
Carina	11	3.9	— 61	24	8	1895	Fleming
Centaurus	13	34.3	— 31	8	7	1895	Fleming

THE NEW ALGOL VARIABLE IN DELPHINUS.

The variable star of the Algol type, B. D. + 17° 4367, in the constellation Delphinus, announced in Circular No. 3, was again found to be faint by Professor Searle on December 17, 1895. From a discussion of the photographic and visual measurements so far made, it appears that its period is about $4^d 19^h 21^m.2$, and that it will again become fainter than the eleventh magnitude from $11^h.6$ to $15^h.8$. Greenwich Mean time, on January 5, 1896.

DECEMBER 20, 1895.

EDWARD C. PICKERING.

WELLS' ALGOL VARIABLE.

A minimum of the Algol star, B. D. $+17^{\circ} 4367$, occurred, as predicted in Circular No. 4, on the afternoon of January 5, 1896. Through the courtesy of Professor Young, observations were obtained at Princeton by Professor Taylor Reed, with the 23 inch equatorial. It was also observed by Mr. W. M. Reed at Andover. Preparations had been made at this Observatory to obtain a series of photographic images of it automatically, each having an exposure of five minutes, to observe it photometrically with the 15 inch equatorial, and also visually with the 12 and 6 inch equatorials. Unfortunately, owing to clouds, few observations were obtained, but these serve to show that the star was faint and diminishing in brightness as expected. Similar preparations were made for the next minimum, January 10, but again clouds prevented observation.

The observations so far obtained show that its time of minimum, uncorrected for the velocity of light, can be closely represented by the formula $J. D. 2412002.500 + 4.8064 E$. The uncertainty in the period does not exceed a few seconds, and will probably be known within a single second as soon as the form of light curve is determined. For nearly two hours before and after the minimum it is fainter than the twelfth magnitude. It is impossible, at present, to say how much fainter it becomes or whether it disappears entirely. It increases at first very rapidly and then more slowly, attaining its full brightness, magnitude 9.5, about five hours after the minimum. One hundred and thirty photographs indicate that, during the four days between the successive minima, it does not vary more than a few hundredths of a magnitude. The variation may be explained by assuming that the star revolves around a comparatively dark body and is totally eclipsed by it for two or three hours, the light at minimum, if any, being entirely that of the dark body. The conditions resemble those of U Cephei, which appears to be totally eclipsed by a relatively dark body two and a half magnitudes fainter than itself, but having a diameter at least one half greater. The variation in light of B. D. $+17^{\circ} 4367$ is more rapid than that of any other star hitherto discovered, and as its range is

greater than that of any known star of the Algol type, its form of light curve can be determined with corresponding accuracy. U Cephei is second in both these respects.

THE NEW STAR IN CENTAURUS.

In Circular No. 4, insert "it" before "follows" in the ninth line. This word was given correctly in the printer's copy, but was omitted in setting the type. The correction was telegraphed to those astronomers who, it was expected, would use it. The Nova follows the nebula N. G. C. 5253, and is north of it. The nebula is assumed to be C. DM. $-31^{\circ} 10536$, magn. 9.5, with which it was originally identified. As seen with a low power the nebula cannot readily be distinguished from a star. Its magnitude on the Cordoba scale by comparison with adjacent stars was estimated by Mr. Wendell as 9.7, and it could hardly have been overlooked in preparing the Cordoba Durchmusterung, in which many adjacent fainter stars are given. The new star could not have been observed at Cordoba unless we assume, first, that it was bright at that time, although invariably too faint to be photographed on fifty nights distributed over six years, and secondly, that the nebula was overlooked at Cordoba while observing fainter objects in the same region. Even if we make these assumptions, the new star still falls in the same class as T Coronae, which was observed in the northern Durchmusterung several years preceding its appearance as a new star.

The various positions of N. G. C. 5253 for 1875 are as follows:—

Dreyer's New General Catalogue	R. A. = $13^h 32^m 51^s$	Dec. = $-31^{\circ} 0'.2$
Cordoba Durchmusterung	R. A. = $13^h 32^m 49^s.6$	Dec. = $-31^{\circ} 0'.3$
Plate B 13965	R. A. = $13^h 32^m 50^s.2$	Dec. = $-31^{\circ} 0' 23''$
Plate B 14072	R. A. = $13^h 32^m 50^s.0$	Dec. = $-31^{\circ} 0' 21''$

The positions of the Nova derived from these plates differ from each other by only $0^s.1$ in right ascension and $1''$ in declination. The mean position for 1875 is R. A. = $13^h 32^m 51^s.8$ Dec. = $-30^{\circ} 59' 58''$. It will be noticed that according to these measures, the Nova follows N. G. C. 5253 by $1^s.7$, and is $24''$ north.

EDWARD C. PICKERING.

JANUARY 31, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 6.

NEW VARIABLE STARS.

An examination of the Henry Draper Memorial photographs of stellar spectra by Mrs. Fleming has led to the discovery of fourteen new variable stars of long period, in addition to those previously announced. The spectrum of the fifth star in the following list is of the fourth type. All of the others have spectra of the third type, having also the hydrogen lines bright, and it was this peculiarity which led to their discovery. The variability has been shown by comparison of a large number of photographs, and the variation has been confirmed in each case by the writer. The following table gives the constellation, the catalogue designation of the star, the approximate right ascension and declination for 1900, the number of plates examined, the photographic magnitude, when brightest and faintest as derived from these plates, and the epoch and period as obtained from the material now available. The epoch is expressed in Julian Days omitting the constant 2410000. It is needless to caution astronomers that these elements cannot safely be used to predict future maxima with accuracy. They generally represent the photographic magnitudes during the last eight years, with an average deviation of one or two tenths of a unit. As, however, the periods and light curves in many cases change, the true law can be determined only from long series of observations. The date of the next maximum, as indicated by the formula, is given in the final column.

CONSTELLATION.	DESIGNATION.	R. A.		DEC.	No. PLATES.	MAGN.		EPOCH.	PERIOD.	MAXIMUM.
		1900.	1900.			BR.	FT.			
		<i>h. m</i>								1896.
Sculptor . . .	—39° 16	0 3.6	—39° 47	43	8.9	<12.1	165	295	May 25.	
Columba . .	A.G.C. 6135	5 15.6	—33 48	24	7.6	11.3	134	225	June 23.	
Canis Minor . . .		7 1.5	+ 9 1	40	10.3	<13.7	174	364	Sept. 11.	
Virgo	+5° 2708	12 57.6	+ 5 43	51	8.8	9.7	..	..	..	
Apus		14 59.3	—71 40	58	9.0	<11.4	..	..	..	
Sagittarius . .	—33° 13234	18 21.4	—33 23	48	8.2	12.3	267	316	July 2.	
Sagittarius . .	—19° 5347	19 8.1	—19 2	47	9.7	11.1	..	..	..	
Sagittarius . .		19 8.7	—18 59	48	9.9	<13.3	..	..	..	
Pavo		19 39.5	—72 1	66	7.6	12.1	156	243	Aug. 29.	
Microscopium .	A.G.C. 28038	20 21.8	—28 35	49	7.4	8.4	..	..	..	
Pavo		20 47.2	—63 5	43	9.6	<12.3	..	..	..	
Grus	—38° 15044	22 19.9	—38 4	57	8.6	11.0	..	..	..	
Grus		22 19.9	—48 57	48	7.2	12.3	90	400	May 10.	
Aquarius . .	—16° 6379	23 47.1	—16 25	42	8.2	9.3	..	..	..	

The third of these stars is near the border of Monoceros.

—33° 13234 was suspected of variability by Dr. Thome (Annals Cordoba Observatory, Vol. XVII, p. xiii).

A. G. C. 28038 is in Sagittarius according to the Uranometria Nova and Heis. March 10, 1896.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 7.

TEN NEW VARIABLE STARS.

The following list of new variable stars includes, as described below, three whose variability was discovered or suspected elsewhere and has been confirmed at this Observatory. The successive columns give the name of the constellation, the designation in the Durchmusterung Catalogues, the approximate right ascension and declination for 1900, the number of plates examined, the magnitude when brightest and when faintest as derived from the photographic charts, and the authority for the variation, the letters H. C. O. indicating that the variation was found at this Observatory.

CONSTELLATION.	DESIGNATION.	R. A.		DEC.	No. PLATES.	MAGN.		AUTHORITY.
		1900.	1900.			BR.	FT.	
Horologium		<i>h. m.</i> 2 22.4	—60° 0'	21	9.7	<12.7	H. C. O.	
Canis Minor	+ 5° 1797	7 43.4	+ 5 40	42	10.3	11.3	H. C. O.	
Pyxis	—24° 7693	9 0.7	—24 41	13	8.9	11.1	Thome.	
Hydra	—22° 7652	9 46.4	—22 32	32	8.2	10.1	H. C. O.	
Centaurus		11 16.1	—61 20	70	9.2	<12.9	H. C. O.	
Libra	—19° 4047	15 6.5	—19 25	. .	. .	. .	H. C. O.	
Scorpius	—35° 11829	17 35.7	—35 12	31	10.7	11.6	H. C. O.	
Cor. Austr. . . .	—37° 12782	18 34.3	—37 56	67	8.9	<11.8	H. C. O.	
Sagittarius	—33° 11076	19 10.0	—33 42	89	6.1	<11.3	Markwick.	
Sculptor	—30° 19448	23 3.7	—30 41	47	8.0	8.9	H. C. O.	

The first star, R. A. $2^h 21^m 39^s$, Dec. $-60^\circ 8'.0$ (1875), has a period somewhat greater than 300 days.

The second star, + 5° 1797, was faint on two plates taken in 1886, and on the photographs taken since then shows variations which though small appear to be real.

The third star,—24° 7693, was suspected of variability by Thome. (Annals Cordoba Observatory, Vol. XVI., p. xxxviii.) As he distinguished this star by an exclamation mark photographs of it, and of six others similarly marked, were examined here by Miss E. F. Leland and the variability of this star was established.

The fourth star,—22° 7652, was found by Miss L. D. Wells from a comparison of two chart plates in her search for stars having large parallaxes, proper motions, or variations in light. This star has been suspected of variability by Espin and Thome. Their names, however, are not included in the above table since almost

all red stars have been suspected of variability, and attempts to confirm suspected variables have failed in a large number of cases. It would obviously be unfair when an astronomer publishes a long list of suspected variables to regard him as the discoverer of any which on later evidence may prove to be variable. It is extremely improbable that the light of the Sun, or of any star, is absolutely constant although the change is in the great majority of cases beyond our present means of measurement. If the distinction between real and suspected variability is not maintained the person first stating that all stars are variable might claim the discovery of all variables subsequently found. It will be seen that this star stands on a wholly different basis from the preceding star since in that case the variability suspected by Thome was the reason for the further examination of this object. This star is $-22^{\circ} 27' 39''$ in the Bonn Southern Durchmusterung. Its spectrum was found to be of the fourth type by Dunér.

The fifth star, R. A. $11^h 15^m 1^s$, Dec. $-61^{\circ} 11' 4''$ (1875), has maxima represented by the formula $J. D. 2,411,100 + 162 E$. The next maximum will accordingly occur on October 21, 1896.

The sixth star, $-19^{\circ} 40' 47''$, ϵ Librae, appears in four of the catalogues of stars measured with the meridian photometer. In Vol. XIV measures on seven nights gave the magnitude 4.87. In Vol. XXIV Table I, three nights gave the magnitude 4.36. In Vol. XXIV Table IV, three nights gave the magnitude 5.02, and in Vol. XLIV, unpublished, three nights gave the magnitude 4.37. The discordance is so great as compared with that of other stars contained in these catalogues that variability of the star seemed to the writer the only reasonable explanation. Accordingly, visual observations were at once undertaken with the meridian photometer, and also by Argelander's method. By the latter method, Mr. Wendell soon confirmed its variability finding it two grades fainter than θ Librae on May 19, and two grades brighter than the same star on June 1, 1896.

The eighth star, $-37^{\circ} 12' 782$, has an approximate period of 136 days.

The ninth star, $-33^{\circ} 14' 076$, is a very remarkable object. It was one of a list of 42 stars suspected of variability sent here for examination by Colonel E. E. Markwick of Gibraltar. A report was sent to him that an examination of several photographs failed to show any sign of variability. A few days later an object having a peculiar spectrum was discovered by Mrs. Fleming. All the plates of the region were examined and its variability established. It was about to be published in

Circular No. 6, when it was found to be identical with the star of Colonel Markwick. It was accordingly reported to him for announcement, but he has kindly authorized its publication here. The photographs show that on eight nights in the summer of 1889, on six nights in 1890, on six nights in 1891, on five nights in 1892, on twelve nights during April, May, June, and July of 1893, the variation of light of this star was comparatively small and irregular. Colonel Markwick's first two observations on July 14 and 19, 1893, showed it of the seventh magnitude and a little brighter than the adjacent star—33° 14068. In August he found it fainter than this star, and by September 12 it was invisible and below the ninth magnitude. A photograph taken here on September 11, showed that it must then have been fainter than the magnitude 9.6 and on October 23, fainter than 11.3. Photographs taken on April 30, May 30, July 8, August 7, August 10, September 12, September 15, November 12, and November 13, 1894 gave the magnitudes 10.9, 10.3, 9.4, 8.6, 8.3, 7.5, 7.6, 6.4, and 6.4 respectively, thus showing a nearly regular increase to its normal brightness, which it retained with irregular variations on twenty-seven nights in 1895. Its magnitude on June 2, 1896 was 6.7. Observations by Colonel Markwick, beginning on August 20, 1894, lead to a similar result. The spectrum of this star is peculiar, and contains bright lines which show evidence of change.

The variation of the tenth star,—30° 19448, is small and irregular.

The spectra of the first, fifth, eighth, and probably the tenth stars are of the third type, having also the hydrogen lines bright. The second and seventh have spectra of the fourth type. These six variables were found by Mrs. Fleming in her regular examination of the Draper Memorial photographs.

MISCELLANEOUS NOTES.

A large number of observations have been made with the meridian photometer to determine the forms of light curves of stars of the Algol type. δ Antliae has hitherto been regarded as belonging to this class and is of interest from the shortness of its period, 7^h 46^m.8, and since it was said to retain its full brightness for less than half of the time. It is difficult to reconcile the last condition with the theory that the variation is due to a dark eclipsing body. One hundred and seventy-seven measures, each containing sixteen photometric settings on δ Antliae were made

with the meridian photometer and give eight normal points. A smooth curve with only two points of inflection can be drawn through these normal points, the greatest deviation being 0.02 magnitudes. From this it appears that δ Antliae is not a star of the Algol type, that its light is continually changing, and that it belongs to the class of variables of short period like δ Cephei and η Aquilae. An interesting feature of this curve is that the time of increase occupies 0.62 of the entire time of variation, the increase of light being slower than the diminution.

γ Pegasi appears to be second in this respect, since, according to the *Astronomical Journal*, Vol. XVI, p. 108, its time of increase is 0.55 of the entire time, and that of other short period variables varies from 0.20 to 0.33. On the other hand, the time of increase is about 0.17 for No. 18 of the variables discovered in the cluster Messier 5. See *Astron. Nach.* Vol. 110, p. 285.

The star β Lyrae is commonly regarded as a variable of short period of the same class as the above. Observations of its spectrum, however, show that two or more bodies, revolving round each other, are present. The light curve found by Argelander may be closely represented by assuming that the primary minimum is caused by the eclipse of the brighter body by the fainter, and the secondary minimum by a similar eclipse of the fainter body by the brighter. This star should therefore be taken from the class of ordinary short period variables and included among the stars of the Algol type.

Mr. Backhouse calls attention to his announcement in "The Observatory" Vol. XVII, p. 402 of the variability of $+0^{\circ} 939$, announced in the *Astrophysical Journal* Vol. 2 p. 198, and to his observations which indicate a period of not more than a year. Variability also suspected by Espin.

The variable star, R Microscopii, is identical with $-29^{\circ} 17235$.

EDWARD C. PICKERING.

June 5, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 8.

COLLECTION OF METEOROLOGICAL WORKS.

The meteorological department of the library of Harvard College Observatory has become, by recent large accessions, the most complete collection of meteorological works in this part of the country. In the early history of the Observatory, many such works were collected by the first and second directors of the institution, Professors W. C. Bond and G. P. Bond; and since then the collection has continued steadily to increase. More recently, three large additions have been made to it; the general library of Harvard University has placed at the Observatory a great number of the meteorological works formerly kept at Gore Hall; the Blue Hill Meteorological Observatory has made a similar transfer; and the New England Meteorological Society, which has lately dissolved its organization, has deposited here the works contained in its library, and also the remaining copies of its own publications. Accordingly, applications for copies of any of the latter publications should hereafter be made to Harvard College Observatory.

Special efforts are now in progress to render still more complete the large collection which has resulted from these additions. It is desired to obtain, either by gift or purchase, copies of the works still wanting. For this purpose, applications have been made to various meteorological institutions for such parts of their publications as are not represented in the existing collection, and orders have been given for the purchase of works which cannot probably otherwise be obtained. It is hoped that by these means the meteorological department of the library may be made so complete as greatly to increase its present value in aiding the studies of meteorologists.

EDWARD C. PICKERING.

June 18, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 9.

STARS HAVING PECULIAR SPECTRA.

A list of stars having peculiar spectra is given in the annexed table. They were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The number of stars of the third type is so large, now amounting to several thousands, that it has not been thought worth while to announce them, but to reserve them for a full list of stars having peculiar spectra to be published in a volume of the Annals. In the following table, the designation of the star in the Durchmusterung catalogues is given in the first column when it occurs in that work. The approximate right ascension and declination for 1900 are given in the next two columns, followed by the Durchmusterung magnitude. The fifth column gives the character of the spectrum, followed by additional remarks when required.

DESIGNATION.	R. A. 1900.	Dec. 1900.	DM. MAGS.	DESCRIPTION.
— 8° 1099	<i>h. m.</i> 5 17.6	— 8° 45'	7.0	Peculiar.
. . .	7 38.3	—70 7	. .	Peculiar.
. . .	10 52.0	—59 51	. .	Peculiar. Resembles η Carinae.
—37° 7905	12 24.0	—37 42	8.8	Type IV.
—34° 11675	17 18.5	—34 6	10.	Type V. Gal. long. 320° 56', lat. —0° 30'.
—39° 12196	17 58.2	—39 20	9.0	Type IV.
. . .	18 17.5	—13 46	. .	Type V. Gal. long. 345° 14', lat. —1° 34'.
. . .	18 22.2	—16 53	. .	Type V. Gal. long. 343° 2', lat. —4° 04'.
—25° 13170	18 23.2	—25 19	7.6	H β bright.
—38° 12843	18 23.4	—38 29	9.5	Type IV.
—31° 15954	18 40.0	—31 28	9.2	Peculiar.
—29° 15574	18 52.4	—29 38	8.9	Peculiar.
—40° 13448	19 37.1	—40 40	9.0	Peculiar. Resembles η Carinae.
—18° 5480	19 40.6	—18 24	9.1	Type IV.
+85° 332	19 43.8	+85 9	9.2	Type IV.
. . .	20 15.6	+16 25	. .	Gascons Nebula. Gal. long. 26° 13', lat. —12° 09'.
—12° 5755	20 26.2	—12 13	9.2	Type IV.
+ 5° 5223	23 44.0	+ 5 50	8.7	Type IV.

Of the seven stars whose spectra are here announced as of Type IV, the first, second, and seventh are normal. The spectra of the others contain rays of much shorter wavelength than ordinary fourth type stars. The spectra of two faint objects announced as peculiar in the *Astron. Nach.* Vol. 135, p. 195 have been shown by recent and better photographs to belong to a different class from that there given. One of these whose approximate position for 1900 is R. A. $17^h 38^m.2$, Dec. $-46^\circ 3'$ announced as a stellar object having the spectrum of a gaseous nebula proves to have a faint continuous spectrum in which the hydrogen lines $H\beta$, $H\gamma$, $H\delta$, $H\epsilon$, and $H\zeta$ are bright, and the bright line at 5007 is absent, so that it more nearly resembles the spectrum of η Carinae. The second object, $-33^\circ 13'53.7$, R. A. $18^h 39^m.3$, Dec. $-33^\circ 27'$ (1900), announced as of the fifth type proves to have the spectrum of a gaseous nebula.

EDWARD C. PICKERING.

July 9, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 10.

SIX NEW VARIABLE STARS.

Lists of suspected variable stars are published in the Results of the National Argentine Observatory, Vol. XVI, p. xxxii, and Vol. XVII, p. xi. These lists contain 527 and 232 stars, respectively, in which the magnitudes were found to be discordant in the observations of the Cordoba Durchmusterung. Especial attention is there called to 26 stars which are indicated by exclamation marks. These stars have been looked for on a number of Draper Memorial photographs by Miss E. F. Leland and the results confirmed by Mrs. Fleming. From this examination, confirmation of the variability of the stars $-24^{\circ} 12600$, $-27^{\circ} 15203$, $-33^{\circ} 185$, $-34^{\circ} 224$, $-38^{\circ} 138$, and $-38^{\circ} 13089$, has been obtained, the change exceeding one magnitude in all cases. The variation of $-22^{\circ} 13401$, $-22^{\circ} 13700$, $-23^{\circ} 8083$, $-24^{\circ} 13621$, $-25^{\circ} 1197$, $-30^{\circ} 12799$, $-33^{\circ} 13321$, $-35^{\circ} 11936$, $-35^{\circ} 14568$, $-37^{\circ} 11462$, $-38^{\circ} 2639$, and $-41^{\circ} 12260$ on from 8 to 25 nights did not exceed two or three tenths of a magnitude and the variation of these stars is accordingly not as yet confirmed. In each of these cases two comparison stars were selected, differing about half a magnitude in brightness, one a little brighter and the other a little fainter, than the suspected variable. The star $-22^{\circ} 15937$ does not appear on photographs taken on 16 nights, although the adjacent star $-22^{\circ} 15939$ is well shown on all. The confirmation by Miss Leland of the variation of $-24^{\circ} 7693$ has already been announced (H. C. O. Circular No. 7). The confirmation by Mr. Robert H. West of the variation of $-25^{\circ} 1602$, $-26^{\circ} 892$, and $-30^{\circ} 375$ has already been announced by him (Astron. Jour. XVI, p. 85). $-25^{\circ} 1602$ and $-30^{\circ} 375$ have also been confirmed here from the examination of the photographs. $-30^{\circ} 19092$ is R Piscis Austrini. The variation of $-33^{\circ} 13234$ was discovered independently by Mrs. Fleming (H. C. O. Circular No. 6). The star in the Bonn Durchmusterung $-22^{\circ} 4346$ and not found by Thome does not appear on photographs taken on 8 nights.

It therefore appears that of these 26 stars, 12 are variable, the variability of 12 is not confirmed, and 2 do not appear on the photographs examined.

The laborious work of taking out all the photographs of the regions containing these six new variable stars, measuring the brightness, the magnitude at maximum and minimum, the period and form of light curve, as has been done for other variable stars discovered here, is now in progress.

EDWARD C. PICKERING.

August 13, 1896.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 11.

A NEW SPECTROSCOPIC BINARY μ^1 SCORPII.

From an examination of the Draper Memorial photographs Professor Solon I. Bailey has found that the star μ^1 Scorpii is a spectroscopic binary. This star is $-37^\circ 11033 =$ S. M. P. 5794. Its approximate position for 1900 is in R. A. $16^h 45^m.1$, Dec. $-37^\circ 53'$, and its photometric magnitude is 3.26. Its spectrum is of the first type and contains the additional lines characteristic of the Orion stars. It, therefore, belongs to Class B according to the notation of the Draper Catalogue. The star μ^2 Scorpii follows about 28^s and is $1'.7$ north, and its photometric magnitude is 3.74. The spectra of both stars, therefore, appear side by side in the photographic plates. In some they are scarcely distinguishable, while in others the lines of the first star are broad and hazy, some of the faint lines appearing distinctly double. The lines in the spectrum of the second star are always single and well defined. One of the components of the binary is fainter than the other, so that the lines of its spectrum are sometimes of greater, and sometimes of shorter, wavelength than those of the brighter component. The difference in intensity also seems to change as if due to a variation in the light of one of the components.

An examination of the plates already sent to Cambridge shows that the spectrum of this star was photographed on October 2, 1892, July 20, 1894, and July 31, 1894. On the first of these plates the lines are single, on the second they are wide and hazy, and on the third they are double. When Mrs. Fleming examined these plates in October, 1894, she recorded on the second of them "Lines double?" and on the third of them "Lines double." They were laid aside for further examination but were overlooked.

The changes are so rapid that they are perceptible in successive plates having exposures of one hour. From a discussion of 52 photographs Professor Bailey has derived a period of 35 hours and a nearly circular orbit.

An independent discussion made here, shows that all the observations, including those of the early photographs, may be represented by the formula, $J. D. 2412374.52 + 1.4462 E$, which gives an average period of $34^h 42^m.5$ with an uncertainty of less than a tenth of a minute. Ten observed times when the lines were single are repre-

sented with an average deviation of 38 minutes each. The maximum deviation is less than an hour. Further observations will, however, be required to make sure that no other assumption is possible for the total number of epochs since 1892. In 19 photographs the lines of the fainter component were found to have greater, and in 14, shorter, wavelengths than those of the brighter component. This was confirmed later, in each case, by the formula.

Only two stars of this class are already known. The first, ζ Ursae Majoris, was found by the writer in 1889. The period appears to be about 52 days but it is irregular, perhaps owing to the presence of a third body, and the time during which the lines are widely separated is short. The second star β Aurigae was found later in the same year by Miss. A. C. Maury. The changes appear to be perfectly regular with a period of a little less than 4 days.

EDWARD C. PICKERING.

August 31, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 12.

STARS HAVING PECULIAR SPECTRA. NEW VARIABLE STARS IN CRUX AND CYGNUS.

A list of stars having peculiar spectra and found by Mrs. Fleming in her regular examination of the Draper Memorial photographs are given in the annexed table. The successive columns give the designation of the star, the approximate right ascension and declination for 1900, the catalogue magnitude, and a brief description of the character of the spectrum, followed by additional remarks when required.

DESIGNATION.	R. A. 1900.	DEC. 1900.	MAGN.	DESCRIPTION.
—39° 3939	<i>h. m.</i> 8 0.1	—39° 43'	2.5	Peculiar. ζ Puppis.
Z.C. 11 ^h 742	11 11.2	—57 23	9	Type IV.
A.G.C. 15946	11 35.0	—72 0	8.5	Type IV.
	12 26.9	—57 1	. .	Type III. Hydrogen lines bright. Variable.
—36° 11341	17 7.0	—37 0	9.1	Gaseous Nebula. Gal. long. 317° 12', lat. —0° 15'.
A.G.C. 22812	16 47.0	—42 12	5.8	Hβ bright. ζ ¹ Scorpii.
A.G.C. 23694	17 24.1	—49 47	2.9	Hβ bright. α Arae.
+44° 3649	20 54.4	+44 24	7.9	Peculiar.
+44° 3679	20 58.9	+44 25	6.8	Peculiar.

The spectrum of the first of these stars is very remarkable and unlike any other as yet obtained. The continuous spectrum is traversed by three systems of lines. First, the hydrogen lines and the line K, which are dark, as in stars of the first type. Second, two bright bands or lines whose approximate wave lengths are 4652 and 4698, which may be identical with the adjacent lines in spectra of the fifth type. Third, a series of lines whose approximate wave lengths are 3814, 3857, 3923, 4028, 4203, and 4505, the last line being very faint. These six lines form a rhythmical series like that of hydrogen and apparently are due to some element not yet found in other stars or on the earth. The formula of Balmer will not represent this series, but if we add a constant term and write $\lambda = 4650 \frac{m^2}{m^2 - 4} - 1032$, we obtain for m equal to 10, 9, 8, 7, 6, and 5, the wave lengths 3812, 3858, 3928, 4031, 4199, and 4504. The deviations from the observed wave lengths have an average value of 3 ten-millionths of a millimetre, are systematic rather than accidental, and although

small appear to be rather larger than might be expected from the errors of observation. A line of wave length 5168 is indicated for $m=4$, and, if present, could be observed visually, or photographed on a plate stained with erythrosin. The only other line found in the spectrum of this star has the wave length 4620, and apparently does not belong to this series.

The fourth star in the table is a new variable in the constellation Crux. A comparison with eight adjacent catalogue stars gives its position for 1875, R. A. = $12^h 25^m 27^s.5$, Dec. = $-56^\circ 53' 25''$. The period is about a year. The photographic magnitude, as derived from 57 plates, is 10.3 at maximum, and fainter than 13.2 at minimum.

The fifth of these objects is N. G. C. 6302, whose spectrum, on a photograph taken on July 9, 1896, is shown to contain the bright lines characteristic of gaseous nebulae.

The presence of the bright hydrogen line in the sixth of these objects was found independently by Miss A. J. Cannon.

The last two objects in the table have similar spectra, containing two bright bands resembling, and perhaps identical with, those in the spectrum of ζ Puppis.

In addition to the above objects a star in the constellation Cygnus, whose approximate position for 1900 is R. A. = $21^h 38^m.8$, Dec. = $+43^\circ 8'$ has been found to be variable by Miss Louisa D. Wells. Its period appears to be about 40 days and its photographic brightness varies from 7.2 to fainter than 11.2, an unusually large range for a variable having so short a period. Its position for 1900, as determined visually by Mr. O. C. Wendell, is R. A. = $21^h 38^m 46^s.21$, Dec. = $+43^\circ 7' 34''.8$.

EDWARD C. PICKERING.

November 2, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 13.

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RELATIVE MOTION OF THE STARS IN THE LINE OF SIGHT.

The determination of the motion of the stars in the line of sight by means of the spectroscope is one of the most important problems in Astronomy. The greatest, and almost the only, objection to the objective prism is that it has thus far failed to determine this quantity. Placing the prism in front of the objective has many advantages over the use of a slit spectroscope. Instead of photographing one star at a time, more than a thousand have, in many instances, been photographed upon a single plate. In fact, our only knowledge of the photographic spectra of the fainter stars is derived from plates obtained with an objective prism. The wave lengths of the lines can also generally be determined equally well by either method, since in the spectrum of almost every star numerous lines are present whose wave lengths have already been accurately determined in the solar spectrum. The wave lengths of other lines can be better determined differentially from these than directly by a comparison spectrum. Nearly all of the Draper Memorial spectra have been photographed by means of objective prisms. Numerous unsuccessful attempts have been made here, ever since this work was undertaken, to determine with an objective prism the approach and recession of the stars (*Annals XXVI*, p. xx). Among other methods which have been tried may be mentioned the use of an absorbing medium like didymium, the variation in length of the spectra, and the use of a point of reference formed by throwing an auxiliary image of the star into the field by means of a small achromatic prism, or by reflecting prisms. Recently experiments have been made by comparing the corresponding lines in the spectra of different stars with their images taken on another plate without the prism and with the film reversed. A discussion of this method by the writer with Mr. Edward S. King has led to the method described below, which promises to determine accurately the relative motion of two or more stars in the line of sight if they are near enough together to be photographed upon the same plate. Let A and B be two such stars, A being at rest and B approaching with such a velocity that a given line in its spectrum is deviated by the amount d , and let a photograph be taken in such a position that the end of shorter wave length

of the spectrum of B is turned towards that of A . Then the distance between the images of the given line in the two spectra will be less by the amount d , than it would be if both stars were at rest. Now let another photograph be taken in which, by turning the prism 180° , the spectra are turned by the same amount, so that the end of greater wave length of the spectrum of B is turned towards that of A . The distance between the two lines will then be increased by an equal amount. If two such photographs are superposed and the images of the reference line in the spectra of A are made to coincide, its images in the spectra of B will deviate by $2d$. To apply this method, a photograph of a region a little east of the meridian is taken in the usual way. Then the telescope is reversed and a second photograph of the same region is taken on a plate with the film side away from the star, so that the photograph is taken through the glass. As both photographs are taken near the meridian the lines will be nearly perpendicular to the length of the spectrum, while, at a large hour angle, if the exposure is long, and the spectra narrow, the lines will cross them obliquely, owing to the differential refraction. Reversing the telescope turns the prisms, and with them the spectra exactly 180° . In making the examination the plates are placed film to film so that the spectra are side by side, and one is moved over the other by means of a micrometer screw. The corresponding lines in the two images of each star in turn are made to coincide, and the difference in the readings gives double the displacement of the line. An error in orienting the plates would affect the results when the stars compared are not in the same right ascension. This source of error may probably be made insensible in several ways, such as by marking a reference line on each plate, or by turning the prisms so that their edges are perpendicular to the line connecting the stars and moving the plate slowly by clock-work. Since the ends only of the lines are compared, narrow spectra may be used, and faint stars may therefore be measured. Experiments are now in progress with a cylindrical lens, by which it is expected that the accuracy of setting on lines in very narrow spectra can be still further increased.

Only preliminary tests of this method can be made at Cambridge at present, as our three best prisms are now in Peru. Two photographs of 101 and 102 Herculis were, however, taken on October 9, 1896, with a single prism, giving poor definition, but showed by inspection that the first of these stars was approaching more rapidly than the second. Measures by Mr. King of the lines H_ϵ and H_γ indicated the relative velocities 87 and 94 kilometres a second respectively. These results are not

corrected for the position of the prism and other sources of instrumental error. The probable error as indicated by the accordance of the individual settings is 5 kilometres in each case. An inspection of two photographs of the Pleiades shows that the relative motions of the seven brightest stars in the group, although perhaps measurable, is not appreciable to the eye, and probably does not exceed 30 kilometres a second.

The advantages of the above method are, first, the directness of the determination of the motion; second, that double the deviation is measured; and third, that as the ends of two similar lines are made to coincide, the accidental errors of measurement are much less than when each in turn is bisected by a spider line. Since each line in the spectrum may be used a large number of independent determinations may be obtained from one pair of plates. On the other hand, as it is only necessary that one line should be in focus, a visual telescope may be employed; that is, one uncorrected for the photographic rays. No corrections need be applied for the motion of the Sun in space or of the Earth in its orbit, since they will affect both stars equally.

EDWARD C. PICKERING.

November 4, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 14.



A NEW SPECTROSCOPIC BINARY IN PUPPIS.

An examination of the Draper Memorial photographs taken at the Arequipa Station shows that the star Lacaille 3105, Argentine General Catalogue 10534, is a spectroscopic binary. The approximate position of this star for 1900 is R. A. = $7^h 55^m.3$, Dec. = $-48^\circ 58'$. Its photometric magnitude is 4.50. The lines in its spectrum were first noticed to be double and its binary character discovered by the writer in February, 1895. Professor Bailey was notified and accordingly secured additional photographs and confirmed the binary character of this star. As in the case of μ^1 Scorpii one component is brighter than the other. A discussion of all the photographs of its spectrum here and at Arequipa gives the mean period $3^d 2^h 46^m$. The times of inferior conjunction can be represented by the formula J. D. $2412777.16 + 3.115 E$. At these times the lines are single, for the next thirty-seven hours the lines are double, the fainter component of each having a greater wave length than the brighter component, and being, therefore, towards the red end of the spectrum. The lines then again become single, and after that, for the remainder of the period are again double, the fainter components having shorter wave lengths, and being, therefore, towards the violet end of the spectrum.

This is the fourth spectroscopic binary of this class in which both components are bright, the others being ζ Ursa Majoris, β Aurigae and μ^1 Scorpii.

EDWARD C. PICKERING.

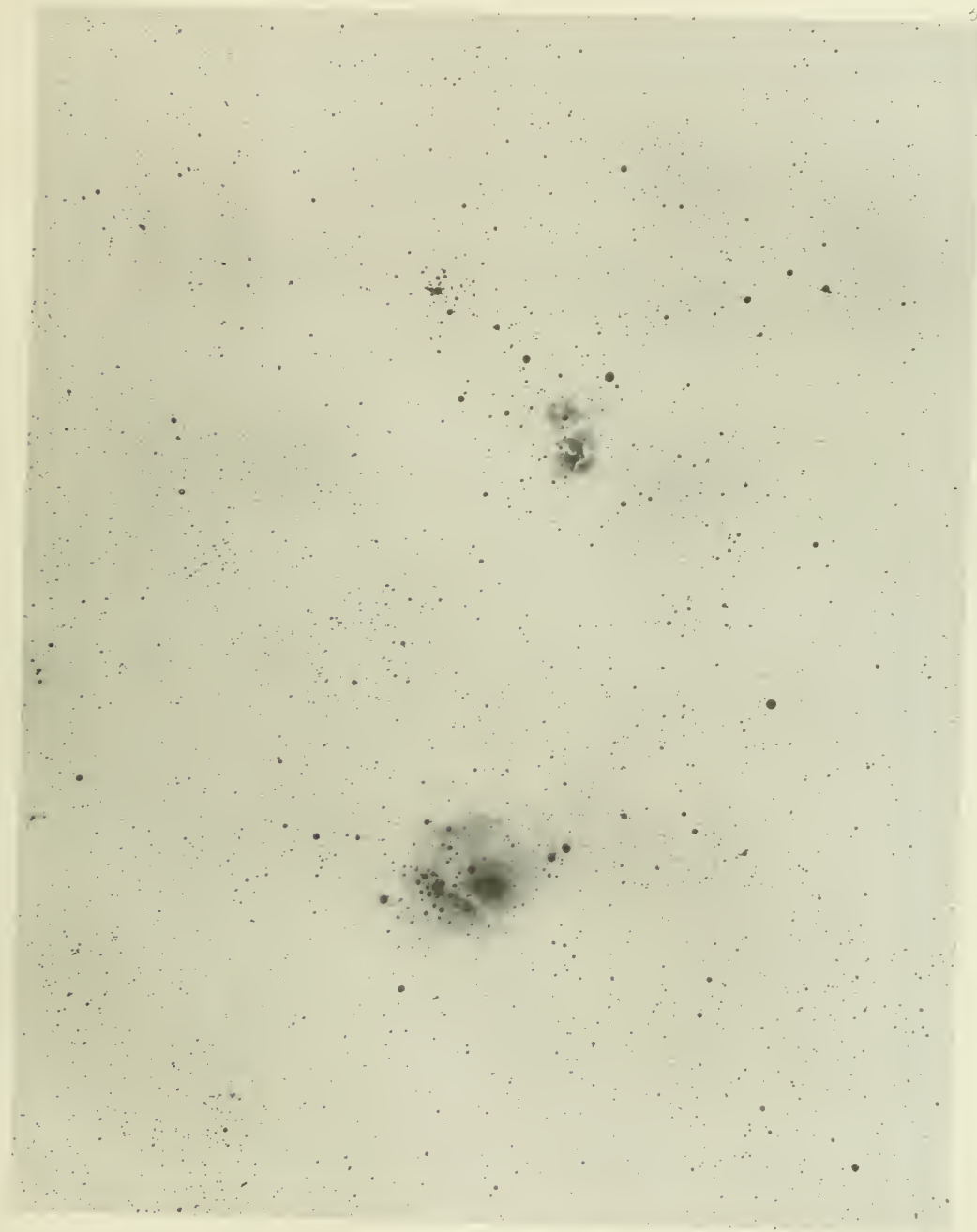
November 17, 1896.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 15.

THE BRUCE PHOTOGRAPHIC TELESCOPE.

The advantages of a doublet for photographing the stars were advocated by the writer in 1883 (*Astron. Register* XXI, 151, *Observatory* VI, 201) and again in 1886 (*Mem. Amer. Acad.* XI, 179). In the latter article (p. 207) it was urged that charts should be photographed of the same size and scale as the charts of Peters and Chacornac, that is on a scale of 6cm. to 1° , and covering a region 5° square. It was there proposed that photographs taken with the 8 inch Bache telescope should be enlarged three times. A similar plan was recommended to the *Congrès Astrophotographique International* in a letter dated December 10, 1887 (*Annexe*, No. 5, p. 95). Later, it was shown in a paper presented to the National Academy at a meeting held in Washington in April, 1888, that the best results might be expected from a telescope having an aperture of 60cm. and a focal length of 343.8cm. The same plan was recommended in a circular dated November 20, 1888, and entitled, *A Large Photographic Telescope*. The generous liberality of Miss Catherine W. Bruce (*The Bruce Photographic Telescope*, June 26, 1889), permitted this experiment to be tried. The instrument was constructed by Messrs. Alvan Clark and Sons, and was mounted provisionally and tested in Cambridge. It was sent to Arequipa last winter by way of the Straits of Magellan, thus avoiding the dangers of transshipment upon the Isthmus of Panama. It arrived safely in Arequipa, was mounted successfully, and is now kept in constant use by Professor Bailey. The excellent results since attained with it are largely due to his skill and perseverance. The accompanying plate serves to illustrate the work already accomplished with this instrument. The original negative was taken on June 11, 1896, with an exposure of 180 minutes upon a plate 14×17 inches. The region covered extends in right ascension from $17^h 40^m$ to $18^h 10^m$, and in declination from $-20^{\circ}.8$ to $-26^{\circ}.5$. About a quarter of this region is represented in the accompanying figure. The upper of the two nebulae is the Trifid Nebula, N. G. C. 6514. The lower and larger nebula is N. G. C. 6523. While this form of photo-engraving is convenient to give a general idea of the appearance of the original negative, it is not adapted to a careful study of the plates. The images are formed of black dots upon a white background and accordingly it is impossible to derive



CENTRE, R. A. = $17^{\text{h}} 56^{\text{m}}$ Dec. = $-23^{\circ} 7'$ TRIFID NEBULA.

Taken June 11, 1896. Exposure 180m. Scale $1' = 0.1$ cm.

from them the true relative positions or magnitudes of the stars represented, as is obvious if they are examined by a magnifying glass. Photogravures have accordingly been prepared of two regions, and a limited distribution, mainly to observatories, is being made of them. They are produced by contact printing from the original negatives and carry out the plan of mapping described above. That is, the photogravures are on a scale of one minute of arc to a millimetre, and cover a region five degrees square. Plate I represents the region whose centre is in R. A. $16^h 10^m$, Dec.— 52° . The original negative was taken on June 6, 1896, with an exposure of 62 minutes. The cluster in the lower part of the plate is N. G. C. 6069. Plate II represents the region whose centre is in R. A. $10^h 40^m$, Dec.— 59° . The original negative was taken on June 1, 1896, with an exposure of 240 minutes. The images are elongated, and this plate is issued as an example of the enormous number of stars which can be shown upon a single map, while Plate I illustrates the character of the images at the centres and corners, and the quality of maps to be expected. It is proposed to issue, from time to time, maps of other portions of the sky, such as the Magellanic Clouds. According to the original plan a map of the entire sky on the scale here represented was to be published. To avoid duplication of work this plan has been abandoned, since the Astrophotographic Congress has undertaken to supply this want. It is believed that a less expensive and more useful scheme will be to furnish contact prints on glass from the original negatives, to such astronomers as will make use of them. A double contact print so closely resembles the original negative that it can only be distinguished from it with difficulty, and for purposes of measurement or exact study is, of course, far more valuable than any paper print.

While announcing the successful completion of the Bruce Photographic Telescope, attention should be called to the courage of the donor who permitted an experiment to be tried on a scale never before attempted, and whose liberality, both in the amount of her gift and in the terms on which it was made, rendered every aid to secure success. It is a great satisfaction to be able to show by these photographs that the results obtained are exactly as expected, and that no unforeseen difficulty interfered with the success of the experiment. Excellent results have already been obtained in photographing the spectra of very faint stars with prisms placed over the object glass of this instrument, and they will be made the subject of a subsequent circular.

December 30, 1896.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 16.

THE SPECTRUM OF ζ PUPPIS.

The announcement was made in Circular No. 12 that the spectrum of the star ζ Puppis contained, in addition to the usual series of lines due to hydrogen, a second series of rhythmical lines. A remarkable relation exists between these two series, from which it appears that the second series, instead of being due to some unknown element as was at first supposed, is so closely allied to the hydrogen series, that it is probably due to that substance under conditions of temperature or pressure as yet unknown. The wave lengths of the lines of hydrogen may be computed by the formula $\lambda = 3646.1 \frac{n^2}{n^2 - 16}$ which is the formula of Balmer, slightly modifying the constant term so that the standard wave lengths of Rowland shall be represented, and substituting $\frac{1}{2} n$ for m . The wave lengths of the lines of hydrogen may be determined by this formula if we substitute for n the even integers 6, 8, 10, 12, etc.

In the annexed table the values of n , the designations of the corresponding lines of hydrogen, their computed wave lengths, their observed wave lengths, and the observed minus the computed values are given in the first five columns. If now we substitute for n the odd integers 5, 7, 9, 11, etc. we obtain the wave lengths of the second series of lines in the spectrum of ζ Puppis, as is shown in the second part of the table. The sixth column gives the value of n , the seventh the corresponding computed wave length, and the eighth and ninth the wave lengths of the lines in ζ Puppis as derived from two series of measures. Miss A. J. Cannon has found that the same series of lines occurs in the star 29 Canis Majoris (H. P. 1380) whose position for 1900 is R. A. = $7^h 14.5^m$. Dec. = $-24^\circ 23'$. As this star has the magnitude 4.8, only three lines of the series are measurable in the photographs so far taken, but, unlike ζ Puppis, many additional lines are present. Measures of the lines common to ζ Puppis are given in the tenth column of the table and the observed minus the computed values for the two stars are given in the last three columns.

n	DES.	COMP.	H	O—C	n	COMP.	ζ	ζ	≈ 29	ζ	ζ	29
4	—	∞	—	.	5	10128.1	.	.	.	.	.	.
6	H α	6563.0	6563.0	0.0	7	5413.9	.	.	.	.	.	.
8	H β	4861.5	4861.5	0.0	9	4543.6	R	R	R	.	.	.
10	H γ	4340.6	4340.7	-0.1	11	4201.7	4199.2	4201.6	4201.1	-2.5	-0.1	-0.6
12	H δ	4101.9	4101.8	+0.1	13	4027.4	4027.1	4026.5	4025.4	-0.3	-0.9	-2.0
14	H ϵ	3970.2	3970.2	0.0	15	3925.2	3924.6	3924.9	.	-0.6	-0.3	.
16	H ζ	3889.2	3889.1	+0.1	17	3859.8	3858.7	3858.6	.	-1.1	-1.2	.
18	H η	3835.5	3835.5	0.0	19	3815.2	3814.7	3817.2	.	-0.5	+2.0	.
20	H θ	3798.0	3798.1	-0.1	21	3783.4	.	3783.4	.	.	0.0	.

The wave lengths here given depend upon the lines of hydrogen and were determined from them by a form of graphical interpolation. The interval between H β and H γ is so great that the errors of interpolation are large for lines in that part of the spectrum. These errors are still greater in the approximate measures given in Circular No. 12, although the results there given for the five lines of the series of shorter wave length than H γ agree closely with those given above. Comparing the spectrum of ζ Puppis with the spectra of other stars, it appears that the four lines between H γ and H β probably coincide with the lines having wave lengths 4472, 4544, 4633, and 4688. The first of these lines is very faint and appears to coincide with the principal line distinguishing stars of the Orion type. The second line is well marked and is the line computed above when $n=9$. The third and fourth lines are bright and coincide with the principal lines in spectra of stars of the fifth type. These four lines are also present in 29 Canis Majoris. Several of the lines in the above table appear bright in stars of the fifth type. Thus in H. P. 1311 the lines for which n equals 8, 9, 10, 11, 12, 13, and 14 are bright. In γ Velorum these lines are also present, some being bright and some dark. The line for which $n=7$ is one of the most conspicuous in the visual spectra of stars of the fifth type. Its wave length has been found by Campbell to be 5412.4, which agrees closely with the computed value 5413.9. He also finds the line 4540, which is probably identical with the line for which $n=9$. From photographs recently taken at Arequipa, but not yet received at Cambridge, it is expected that the wave lengths of all these lines can be accurately determined.

EDWARD C. PICKERING.

January 12, 1897.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 17.

STARS HAVING PECULIAR SPECTRA.

A list of stars having peculiar spectra is given in the annexed table. With four exceptions noted below they were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The designation of the star, its approximate right ascension and declination for 1900, its catalogue magnitude, and a brief description of its photographic spectrum are given in the successive columns of the table. When the object is not a catalogue star its position as derived from a photograph, is given in the notes following the table.

DESIGNATION.	R. A. 1900.		DEC. 1900.	MAGN.	DESCRIPTION.
	<i>h</i>	<i>m</i>			
.	0	25.6	—46° 58'	. .	Type III. Hydrogen lines bright. Variable.
.	5	35.1	—69 52	. .	Gaseous Nebula. Gal. long. 247° 08', lat. —31° 43'.
A. G. C. 6633	5	36.0	—34 8	2.5	H β bright, superposed on broad dark line. <i>a</i> Columbae.
A. G. C. 9313	7	14.5	—24 47	4.6	Peculiar. 30 Can. Maj. Resembles ζ Puppis.
A. G. C. 10182	7	43.9	—25 42	5.3	H β bright. <i>o</i> Puppis.
—41°3911	8	10.8	—41 24	10	H β , H γ , H δ , and H ζ bright. Resembles η Carinae.
A. G. C. 12465	9	4.8	—70 8	5.2	H β bright, superposed on broad dark line. E Carinae.
A. G. C. 17542	12	48.8	—56 37	5.5	H β bright. Companion to μ Crucis.
.	13	31.1	—55 58	. .	Peculiar. Variable.
A. G. C. 19273	14	8.0	—56 37	5.6	H β bright.
.	16	21.1	—43 26	. .	Type IV.
A. G. C. 22640	16	39.2	—46 54	7.4	Bright band, wave length about 4700.
—36°11341	17	7.0	—37 0	9.1	Gaseous Nebula. Gal. long. 317° 13'. lat. —0°45'.
.	17	11.6	—45 52	. .	Type IV.
—7°4689	18	39.1	— 7 12	8.2	H β bright.
—7°5141	19	55.7	— 7 39	9.8	Type IV.
.	20	8.5	—44 43	. .	Peculiar. Variable.
A. G. C. 29191	21	11.5	—39 15	7.3	Peculiar.
A. G. C. 31272	22	55.0	—23 4	8	Peculiar.

The position of the first star is R. A. = 0^h 24^m 23^s.9, Dec. — 47° 6' 3" (1875). Dr. De Lisle Stewart, at Arequipa, called attention to the spectrum of this star on a plate taken with the Bruce 24 inch telescope, adding the remark

"bright lines (hydrogen?)." On examination by Mrs. Fleming it proved to be variable having a spectrum of the type characteristic of such stars.

The position of the second object which is in the larger Magellanic Cloud is R. A. = $5^h 35^m 20^s.0$ Dec. — $69^\circ 52' 51''$ (1875).

The bright band in ξ Puppis having wave length 4688 is dark in the spectrum of β Canis Majoris. This spectrum, like that of the adjacent star, 29 Canis Majoris, was found by the writer to contain the additional hydrogen lines having wave lengths 3925, 4027, 4202, and 4544.

The bright line in the spectrum of α Puppis was found independently by Dr. Stewart.

The position of the ninth star is R. A. = $13^h 29^m 32^s.3$, Dec. — $55^\circ 50' 10''$ (1875). The spectrum of this star may resemble that of ξ Puppis, since it contains two bright lines which may coincide with the lines having wave lengths 4633 and 4688 in the spectrum of that star. ξ Puppis, 29 Canis Majoris, β Canis Majoris, and this star may form a subdivision of Type V. All of these stars are near the central line of the Milky Way.

The bright line in the spectrum of A. G. C. 19273 was found by Miss A. J. Cannon.

The position of the eleventh star is R. A. = $16^h 19^m 15^s.9$, Dec. — $43^\circ 22' 49''$ (1875).

The thirteenth object, — $36^\circ 11341$. is N. G. C. 6302.

The position of the fourteenth star is R. A. = $17^h 9^m 46^s.1$, Dec. — $45^\circ 49' 44''$ (1875).

The position of the seventeenth star is R. A. = $20^h 6^m 45^s.2$, Dec. — $44^\circ 46' 59''$ (1875). Dr. Stewart noted "bright line star (faint)" on a Bruce photograph. An examination by Mrs. Fleming shows that the star is variable and that the spectrum is peculiar.

DISTRIBUTION OF STARS IN CLUSTERS.

Professor Bailey has recently made a count of the stars in the vicinity of several clusters. An enlargement was made of a photograph of the Pleiades taken with the Bruce telescope and having an exposure of six hours. A region $2''$ square, with γ Tauri (Aleyone) in the centre was divided into 144 smaller squares, each $10''$

on a side. The stars in each of these squares were then counted. The total number thus found was 3972, an average of 28 in each square. The 42 squares including the brighter stars in the group contain 1012 stars, an average of 24 per square. It therefore appears that the total number of stars in the region of the Pleiades is actually less than that in adjacent portions of the sky, of equal area, and it is much less than the corresponding number in many parts of the Milky Way. The Pleiades must, therefore, be regarded, first as a group consisting of comparatively bright stars, secondly, if we omit the bright stars, the number of faint stars will be much less than in the adjacent portions of the sky. This absorption of the faint stars is probably due to the nebulosity surrounding this group. A similar absence of faint stars is noticeable near other diffused nebulae, for example, that surrounding N.G.C. 6726-7. This condition would be explained if we assume that stars have not yet been formed by the condensation of this portion of the nebula or that the latter is less distant and slightly opaque.

A similar count was made of ten regions 6' square, in the vicinity of η Carinae. The plate used was taken with the 24 inch Bruce telescope, and had an exposure of four hours. From this count it appears that in a region 5° square, and represented in Plate 2. described in Circular No. 15, the total number of stars was about 250,000, while the number contained on the entire plate exceeded 400,000.

EDWARD C. PICKERING.

March 30, 1897.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 18.

VARIABLE STAR CLUSTERS.

Announcement was made in Circular No. 2 of the discovery by Professor Solon I. Bailey of numerous variable stars in certain globular stellar clusters, and their absence in other objects which apparently belong to the same class. Since then he has found many more of these variables, so that their total number including a few found here is now 310, distributed as follows: — In N. G. C. 104 (47 Tucanae), 6; in 362, 8; in 1904, 1; in 5139 (ω Centauri), 60; in 5272 (Messier 3), 113; in 5904 (Messier 5), 63; in 5986, 1; in 6254, 1; in 6266, 9; in 6626, 3; in 6656, 5; in 6723, 2; in 6752, 1; in 7078, 27; in 7089, 8; and in 7099, 2. In the greater portion of these clusters about 1000 stars were examined. In Messier 3 about one-ninth of the stars are variable while in others like N. G. C. 6205 (the great cluster in Hercules), out of nearly 2000 stars not a single variable has been found. The positions of 62 of the stars in Messier 5 are given in the Harvard Observatory Annals XXVI, 243, 246. The light curve and period of one of them are given in the Astron. Nach. CXL. 285.

SOUTHERN DOUBLE STARS.

A distinguishing feature of the climate of Arequipa is the great steadiness of the air. The value of this location as an observing station is largely due to this fact. Good definition, under high powers, is obtained there on many more nights than in Europe, or in the United States, where nine-tenths of the observatories of the world are at present located. A search for close double stars may, therefore, be advantageously made at Arequipa, and accordingly, in 1891 all the stars of the sixth magnitude and brighter, south of declination -30° , were examined for close companions. The stars in one quarter of the region, and included between 12^h and 18^h of right ascension were examined by Professor William H. Pickering, and the remaining three-quarters by Professor Solon I. Bailey. The instrument used was the 13 inch Boyden telescope. A power of 450 was ordinarily employed.

The stars whose numbers in the Argentine General Catalogue are given below were found to have companions whose distances were estimated not to exceed 30". Stars already announced as double in the Catalogues of Herschel and Russell are not included. When two or more companions were noted the letter T is inserted after the number : —

A. G. C. 451 T, 480 T, 684, 702, 780, 1024 T, 1197, 2412, 2992, 3487 T, 4368, 4395, 4845, 5295, 6494, 6633, 7914, 7990 T, 8093 T, 9234, 10188, 10335, 10496, 11097, 11712, 11727, 11887, 12035, 12101, 12180, 13135, 15795, 16200, 16541 T, 16612 T, 16690 T, 16793, 16845, 16992, 17403, 17440, 17504, 17541 T, 17572, 17907, 17936, 18174 T, 18492 T, 18700, 18773, 18863 T, 18931 T, 18980, 19129, 19273 T, 19280, 19295, 19540 T, 19578 T, 19597 T, 19679, 19697, 19741, 19746, 19873, 19916, 19934 T, 19980, 19988, 20049, 20170, 20203, 20444 T, 20466 T, 20649, 20695, 20806 T, 20811, 20861, 20909 T, 21078 T, 21153, 21177, 21319 T, 21374, 21421 T, 21499 T, 21559, 21694 T, 21767, 21828, 21887, 21921, 21974, 21995, 22124, 22159, 22534 T, 22582, 22598, 22604, 22949, 22970, 23018, 23035 T, 23098, 23126 T, 23358, 23397 T, 23448 T, 23486, 23515 T, 23549 T, 23597 T, 23603 T, 23785 T, 23973, 24148, 24182, 24218, 24407 T, 24483, 24557, 24570, 24624, 24703, 24888, 25137, 25259, 25527, 25548, 26026 T, 26041, 26287, 27354, 27909, 28851, 29314, 29368, 30425, 30814, and 32446.

SPECTRUM OF ζ PUPPIS.

In Circular No. 16 it was shown that a line having wave length 5413.9 probably exists in the spectrum of this star. This line is clearly visible on three photographs of this star taken in Arequipa on isochromatic plates.

EDWARD C. PICKERING.

July 29, 1897.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 19.

LARGE MAGELLANIC CLOUD.

Stars whose spectra are of the fifth type consisting mainly of bright lines have hitherto been found only near the central line of the Milky Way. Of the 67 stars of this type so far discovered the average deviation from this line is $2^{\circ} 39'$. For only one object, whose distance is $17^{\circ} 39'$, does the deviation exceed 9° . It is difficult to explain this very close approach to a great circle as these stars fall in a band much narrower than the Milky Way itself. This law of distribution is one of the most important results attained by means of the Henry Draper Memorial. The two Magellanic Clouds closely resemble the Milky Way in appearance, although completely detached from it, and distant from its central line by about 33° and 45° respectively. From an examination of the photographs of the spectra of the stars in the Large Magellanic Cloud, recently taken with the Bruce Photographic Telescope, Mrs. Fleming has discovered six stars whose spectra are of the fifth type; also that bright hydrogen lines are present in the spectra of seven stars of the first type, and that the spectra of six known nebulae are gaseous and not continuous. The power of the instrument and the quality of the photographs are shown by the fact that, with one exception, all of these stars are so faint that they have not been included in any of the star catalogues as yet published. A list of these objects is given in the following table. The successive columns contain the approximate right ascensions and declinations for 1900, the galactic longitudes and latitudes of the nebulae and stars of the fifth type, and a brief description of the objects.

R. A. 1885	Dec. 1885	Gal. Long.	Gal. Lat.	DESCRIPTION.
<i>h m</i>				
4 54.6	-69° 21'	247° 14'	-35° 16'	Gaseous nebula. N. G. C. 1743.
4 56.4	-66 37	243 54	-35 44	Type V. Brightest star in N. G. C. 1761.
4 56.5	-66 34	243 51	-35 44	Gaseous nebula. N. G. C. 1763.
5 14.0	-67 34	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 1871.
5 18.9	-69 21	...	...	Type I. H β , H γ , and H δ bright. Variable. In N. G. C. 1910.
5 20.1	-69 45	247 10	-33 1	Type V. In N. G. C. 1918.
5 25.6	-68 33	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 1949.
5 30.4	-67 30	244 24	-32 20	Type V.
5 32.0	-71 6	248 37	-31 51	Type V.
5 35.2	-69 49	247 5	-31 43	Type V.
5 35.6	-67 39	244 32	-31 50	Gaseous nebula. N. G. C. 2029.
5 37.2	-69 26	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 2050.
5 39.3	-69 8	246 15	-31 24	Gaseous nebula. N. G. C. 2070. 30 Doradus.
5 39.5	-69 5	246 11	-31 23	Type V.
5 40.6	-69 49	247 2	-31 15	Gaseous nebula. N. G. C. 2079.
5 40.6	-69 42	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 2080.
5 40.6	-69 42	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 2080.
5 40.7	-69 27	246 37	-31 16	Gaseous nebula. In N. G. C. 2081.
5 41.0	-69 26	...	...	Type I. H β , H γ , and H δ bright. In N. G. C. 2081.

The fifth star is variable and has a range of rather more than one magnitude. It is identical with Gilliss No. 3092.

The tenth object is identical with the second object, announced as a gaseous nebula in Circular No. 17. Small gaseous nebulae and faint fifth type stars can be distinguished photographically only by the wave length of the principal line in their spectra. Accordingly, on the Bache plates the bright line was assumed to be due to a gaseous nebula and was identified with a faint adjacent star. Two Bruce plates show that the spectrum is that of a fifth type star following 0^m.1, north 3'.

The gaseous character of the nebulosity surrounding 30 Doradus is well known. These photographs show that several objects closely adjacent to it have bright lines in their spectra.

After the above description had been prepared a letter was received from Peru, from which it appeared that the presence of bright lines in the spectra of several of these stars had already been found by Dr. Stewart at Arequipa. His description of each object is given below preceded by its right ascension:—

R. A. 4^h 54^m.6. Four bright lines including H β , H γ , and H δ .

R. A. 5^h 14^m.0. H β and H γ bright.

- R. A. 5^h 18^m.9. H β , H γ , and H δ bright.
 R. A. 5^h 20^m.1. H β bright and broad.
 R. A. 5^h 25^m.6. H β somewhat bright, not intense.
 R. A. 5^h 32^m.0. H β somewhat bright, broad, not intense.
 R. A. 5^h 35^m.2. H β bright and broad, partial spectrum only visible.
 R. A. 5^h 37^m.2. H β , H γ , and H δ bright.
 R. A. 5^h 39^m.3. H β and H δ bright.
 R. A. 5^h 40^m.6 (first). H β bright and broad.
 R. A. 5^h 40^m.6 (second or third). H β , H γ , and H δ bright and broad.
 R. A. 5^h 41^m.0. H β , H γ , and H δ bright and sharp.

The line called H β by Dr. Stewart in the first, ninth, and tenth of these objects is probably the line 5007, characteristic of gaseous nebulae. The line called H β in the fourth, sixth and seventh objects is probably the line 4688, characteristic of spectra of the fifth type.

EDWARD C. PICKERING.

September 28, 1897.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 20.

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SPECTRUM OF A METEOR.

The photographs of the spectra of the stars taken at the Harvard College Observatory as part of the Henry Draper Memorial differ in two respects from those ordinarily taken elsewhere. Instead of using a spectroscope with a slit, in which but one star is photographed at a time, a large prism is placed over the object glass of the telescope and thus spectra of all the bright stars in the field of view are obtained. The number of stars photographed simultaneously is still further increased by substituting for the object glass a portrait lens like that used by photographers, only larger. The field of view is in this way increased from two degrees square to ten degrees square, and a photograph is obtained of the spectra of all the brighter stars in this large region. Many thousand plates, covering the entire sky, have been taken in this way at the Cambridge and Arequipa Stations of this Observatory. All have been examined by Mrs. Fleming and, as a result, numerous remarkable objects have been discovered. One of the latest is the spectrum of a meteor which has thus been photographed for the first time. Since it is impossible to foresee when the bright meteors will appear, or what path they will follow, a photograph will be obtained only when one happens to cross the field of the telescope. A number of trails of meteors have been obtained, both here and elsewhere, when charts of the stars were photographed, no prism being used. When the prism was in place no meteor bright enough to leave a noticeable trail has heretofore been photographed on the many thousand plates examined. At about 11 P. M. on June 18, 1897, however, when the 8-inch Bache telescope at Arequipa was directed towards the constellation Telescopium, a bright meteor appeared in right ascension $18^h 19^m$, declination $-47^\circ 10'$, and passed out of the field at right ascension $18^h 29^m$, declination $-50^\circ 30'$. The spectrum consists of six bright lines whose intensity varies in different portions of the photograph, thereby showing that the light of the meteor changed as its image passed across the plate. The approximate wavelengths of these lines are 3954, 4121, 4195, 4344, 4636, and 4857, and their

intensities are estimated as 40, 100, 2, 13, 10, and 10, respectively. The first, second, fourth, and sixth of these lines are probably identical with the hydrogen lines $H\epsilon$, $H\delta$, $H\gamma$, and $H\beta$, whose wavelengths are 3970, 4101, 4341, and 4862. The fifth line is probably identical with the band at wavelength 4633, present in spectra of stars of the fifth type and forming the distinctive feature of the third class of these stars. The third line, which is barely visible, is perhaps identical with the band at wavelength 4200, contained in these stars (Astron. Nach. 127, p. 1).

It will be noticed that of the four hydrogen lines in the spectrum of the meteor, $H\delta$ is the most intense. This is also the case in the spectrum of α Ceti and of many other variable stars of long period. In some variables of long period $H\delta$ and $H\gamma$ are equally intense, while in others $H\gamma$ is the more intense. In some stars of the first type in which the hydrogen lines are bright, like γ Cassiopeiae, the line $H\beta$ is much more intense in the photographic spectrum than any of the other lines, while in the spectra of stars like P Cygni and η Carinae, $H\delta$, $H\gamma$, and $H\beta$ are nearly equally bright. These results show an important resemblance between meteors and stars having bright lines in their spectra, and may aid in determining the conditions of temperature and pressure in these bodies. Since bright meteors sometimes appear during the November meteoric shower a special effort will be made here to obtain photographs of them, both trails and spectra, on November 13.

EDWARD C. PICKERING.

November 8, 1897.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 21.

A VARIABLE BRIGHT HYDROGEN LINE.

The presence of the bright hydrogen line $H\beta$ in the spectrum of the star A. G. C. 9181 was found from the Draper Memorial photographs in 1895 and was announced in the *Astrophysical Journal*, Vol. 1, page 411. From a comparison of photographs of this object taken on different dates Miss A. J. Cannon finds that this line is variable. On October 5, 1892, it was invisible. On November 28, 1894, it was about half as bright as the corresponding line in A. G. C. 9198, ω Canis Majoris. On April 27 and 30, 1895, the line in A. G. C. 9181 was distinctly the brighter of the two, while in January, 1897, it was again invisible. From a large number of photographs of this object taken recently it appears that this line which was bright in October, 1897, is now, December 27, invisible.

A NEW SPECTROSCOPIC BINARY.

From an examination of the Draper Memorial photographs Mrs. Fleming finds that the star A. G. C. 20263, β Lupi, is a spectroscopic binary. The period has not yet been determined but photographs are being taken for this purpose.

Measures of the spectroscopic binaries μ^1 Scorpii and A. G. C. 10534 show that the relative velocities of the components are approximately 460 km. and 610 km. respectively. The velocities are therefore much greater than in the case of ζ Ursae Majoris and β Aurigae. The separation of some of the lines amounts to as much as 9 tenth-meters.

EDWARD C. PICKERING.

January 1, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 22.

PHOTOGRAPHIC MAGNITUDES.

In determining the photographic magnitudes of the stars it is a matter of great importance to know how much their relative brightness will vary on different plates, or on different portions of the same plate. It is especially important to determine the amount of this error since it is not easily eliminated and has been supposed to be large by some persons not familiar with stellar photographs. A moment's investigation of photographs of the same portion of the sky shows that this source of error is small, so small that it is not readily determined by direct measurement. The uniformity of different portions of the film is shown by allowing the stars to trail over the plate. The different portions of the trails appear equally intense, and no variation is perceptible to the eye. A much more delicate test was found in the discussion of a series of measures, made by Miss E. F. Leland, of the variables discovered by Professor Bailey in the Cluster Messier 5. Sixty-three of these variables were compared on 41 plates by Argelander's method, with a sequence of comparison stars. Estimates were made of the difference in grades of each variable from the next brighter and the next fainter star of the sequence. The sum of these differences gives the interval between the comparison stars and combining all the results gives, in general, several measures of each interval on each plate. Each comparison star in turn may then be regarded as a variable and its changes in light determined from the next brighter and next fainter star of the sequence. Comparatively few measures were made of the six brightest and the three faintest stars of the sequence. The five intermediate stars were measured on 41, 39, 38, 30 and 30 photographs respectively. The corresponding ranges in the measures derived from each plate, none being rejected, were 0.14, 0.10, 0.12, 0.15, and 0.08 magnitudes, and the average deviations, 0.02, 0.01, 0.02, 0.03 and 0.02. The largest residual was 0.10 and this depended upon two estimates only. We find, therefore, that on the average, five stars were measured on 35 plates with a range

of 0.12 magnitudes and an average deviation of 0.02 magnitudes. The total number of estimates from which these results are derived is 4294. The average deviation 0.02 includes: 1st. The errors of observation which are increased by the fact that four estimates enter into each determination, but are diminished since on the average twelve determinations were made of each interval on each plate. 2d. Errors due to neglecting hundredths of a magnitude, the computation so far being made only to tenths. 3d. Errors due to irregularities in the film which enter with their full value into the result. Since the combined effect of these three sources of error is only ± 0.02 , it is evident that neither of them can be large. The errors due to the film are in fact so small that there is no evidence that they exist and more delicate methods of measurements are required to render them perceptible.

EDWARD C. PICKERING.

January 4, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 23.

THE VARIABLE STAR U PEGASI.

Much difficulty has been experienced in determining the nature of the variations in the light of this star. Mr. Chandler states that he at first supposed that it was a star of the Algol type having a period of $2^d.06$ or $2^d.07$. It was then observed by Mr. Yendell who confirmed the variability and still regarded it as of the Algol type, but with a period of $0^d.69$. Mr. Chandler, under date of October 26, 1895, announces in the *Astron. Journ.* 15, p. 181, that the period is $5^h 31^m 9^s.0$ which "is probably only a moderate fraction of a second in error," that it is not of the Algol type, but that the times of increase and decrease are equal. Mr. Yendell (*Astron. Journ.* 16, p. 78) states that the time of increase varies from $1^h 28^m$ to $3^h 41^m$. Again, Mr. Chandler (*Astron. Journ.* 16, p. 107) announces that the period is $5^h 32^m.25$, that it is perfectly regular, and that previous discrepancies are due to a large subjective error amounting to $0^m.6\rho$, in which ρ is the parallactic angle. The correction for this error will sometimes increase and sometimes diminish the observed time of minimum by as much as half an hour. He also states that the decrease in light is more rapid than the increase, and, referring to the short period variables η Aquilae and δ Cephei, that "we may therefore regard U Pegasi, provisionally, as a type of variability distinct from this class of stars, as it evidently is from those of the Algol type."

Owing to these uncertainties it seemed desirable to determine the true form of the light curve photometrically, especially as such observations are free from the subjective error mentioned above, since the images compared are constantly interchanged. Assuming the light curve to be constant, it appeared possible to determine its form from observations made during a single evening. Accordingly, measures were made by Mr. O. C. Wendell with the polarizing photometer (*Astrophys. Journ.* II, 89) attached to the 15 inch equatorial telescope of the Harvard College Observatory. The results for a single evening, December 28, 1897, are contained in the annexed table, the first column giving the Greenwich Mean Time, and the second the photometric magnitude found by adding the observed difference in magnitude between U Pegasi and the comparison star, $+15^{\circ}49'16''$, to 8.90, the photometric magnitude of the latter star. These observations are also indicated by the crosses in the

figure. The third column gives the residuals found by subtracting from the magnitude given in the second column that derived graphically from all the observations.

OBSERVATIONS ON DECEMBER 28, 1897.

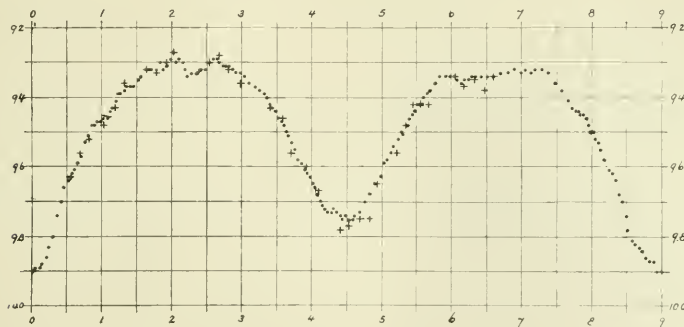
G. M. T.	Magn.	O—C	G. M. T.	Magn.	O—C	G. M. T.	Magn.	O—C	G. M. T.	Magn.	O—C
<i>h.</i> 10 26.9	9.63	.00	<i>h.</i> 11 55.4	9.27	— .02	<i>h.</i> 13 58.6	9.67	— .02	<i>h.</i> 15 21.0	9.42	— .02
10 34.2	9.56	— .01	12 25.8	9.30	.00	14 17.5	9.78	+ .04	15 26.8	9.42	.00
10 42.2	9.52	+ .01	12 33.4	9.28	— .02	14 24.5	9.77	+ .02	15 33.2	9.42	+ .04
10 55.3	9.48	+ .02	12 41.2	9.32	+ .01	14 34.0	9.75	+ .02	15 56.9	9.34	.00
11 4.7	9.43	+ .02	12 51.1	9.36	+ .03	14 43.0	9.75	+ .07	16 3.0	9.37	+ .02
11 12.4	9.36	— .02	13 17.4	9.43	+ .01	14 50.0	9.65	.00	16 13.3	9.35	+ .01
11 31.3	9.32	— .01	13 27.2	9.46	— .01	15 7.0	9.56	+ .03	16 21.2	9.38	+ .04
11 40.0	9.33	+ .02	13 36.0	9.56	+ .03	15 15.0	9.48	.00	16 29.6	9.34	.00
11 48.6	9.30	.00	13 48.7	9.60	— .01						

Each observed magnitude is derived from the mean of four sets of four settings each, the photometer being reversed between the second and third sets, and the positions of the images of the stars interchanged after the second setting of each set. The magnitudes derived from each pair of sets differ on the average ± 0.04 magn. The average values of this quantity during the seven successive hours of observation were 0.06, 0.03, 0.04, 0.03, 0.04, 0.04, and 0.04 respectively. As they show no progressive increase it is evident that the fatigue of the observer did not sensibly affect the accuracy of the observations. The accuracy is also unaffected by the altitude which was only $5^{\circ}.6$ at the end of the series. No correction has yet been applied for differential absorption, which is small but sensible, although the distance between the stars compared is only $15'$. The computed probable error of a single set of four settings from these differences is ± 0.024 magn. The average value of the residuals in the third column is ± 0.017 , only one being greater than 0.04.

It is obvious from an inspection of these observations that the star had nearly the same brightness after an interval of $4^h 30^m$, at first indicating that the variable had this period and not $5^h 31^m$. But later observations showed that the phenomena were not quite so simple. Assuming the period $4^h 30^m$ it soon appeared that the even minima were fainter than the odd. Observations continued through even minima on four nights gave the minimum brightness of U Pegasi, including errors of

observation, 9.94, 9.94, 9.92, and 9.85 respectively, while corresponding measures of odd minima gave the magnitudes 9.78, 9.78, and 9.75. It thus became evident that the period should be doubled, and plotting the observations a light curve was formed closely resembling that of β Lyrae. The formula $J. D. 2413514.6157 + 0^d.37478E$ has been adopted which closely represents the observations recently made and also a few less accordant observations made here in 1895. Changing the period by two seconds, to $0^d.3748$, would alter the times of minima in 1895 by about an hour while the uncertainty is only a small fraction of this amount. The period may, therefore, be assumed to be $8^h 59^m 41^s$. The magnitude at maximum is 9.30, at primary minimum 9.90, and at secondary minimum, 9.75.

PHOTOMETRIC OBSERVATIONS.



The above figure represents the observations on a scale such that in the ordinates one division corresponds to a tenth of a magnitude, and in the abscissas to 30 minutes. All the observations made by Mr. Wendell on eight nights are included, none being rejected for discordance. In fact, the most discordant set of sixteen settings differs from the mean curve by less than a tenth of a magnitude. Each dot represents 80 settings, the method of overlapping means, in common use in meteorology, being employed. The observations of December 28, as stated above, are represented by crosses, each representing the result of sixteen settings. The total number of settings was 2784 and the entire time of observation including rests, about 30 hours.

If we neglect the difference between the primary and secondary minima, reduce the half period to fractions of a day, and multiply it by 16 we obtain the product $2^d.99824$, or very nearly three days. Therefore, the phases recur at nearly the same times every three days. If we multiply the period $5^h\ 32^m\ 15^s$ by 13 we obtain $2^d.99948$, or very nearly the same quantity. In either case, therefore, the phases would recur at the same times every three days, but with the second period the interval between successive minima would be greater than with the first period in the ratio of 16 to 13. If then we used the second period we should find the observed minima in error by an amount equal to three-thirteenths of the hour angle, or expressed in minutes $0^m.92h$, in which h is the hour angle expressed in degrees. Since the latitude of Cambridge is $+42.4$ and the declination of U Pegasi is $+15.4$ it follows that when h is small we may write $h = 0.61p$ and $0^m.92h = 0^m.56p$ which agrees very nearly with $0^m.6p$ the correction found empirically by Mr. Chandler from his observations. The coefficient becomes larger with large hour angles having the values 0.61, 0.74, and 0.91 for $h = 15^\circ, 30^\circ$, and 45° , respectively. It, therefore, follows that by the application of the correction $0^m.6p$ not only were the observed times of minima changed in some cases by more than half an hour but an error of more than an hour was introduced into the half period. An arbitrary correction proportional to the parallactic angle is not to be recommended, since by assuming different values of the coefficient, very different values of the period will be found.

From the above discussion it appears that U Pegasi is no longer the variable star having the shortest period known. This position appears to be held by the variable ω Centauri 19, discovered by Professor Bailey who finds its period to be $7^h\ 11^m$. Although U Pegasi can no longer be regarded as an example of that peculiar class of short period variables having a single maximum in which the decrease is more rapid than the increase, this class is still represented not only by δ Antliae, but by ω Centauri 24, which Professor Bailey finds to decrease twice as rapidly as it increases, while ω Centauri 45 increases at least five times as fast as it diminishes.

EDWARD C. PICKERING.

January 14, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 24.

VARIABLE STAR CLUSTERS.

Since the announcement made in Circular Nos. 2 and 18, of variables discovered in clusters, a further examination of the clusters ω Centauri, Messier 3, Messier 5, and N. G. C. 7078 has been made by Professor Bailey. As a result, the numbers of known variables in these clusters have been increased by 62, 19, 22, and 24 respectively, making the total numbers 122, 132, 85, and 51, or 390 in all four clusters. Adding to these the 47 already announced in other clusters, makes the total number 437.

NEW VARIABLE STARS.

When a new variable star is discovered at this Observatory it is the custom to collect all the photographs of the region containing it and to derive its photographic magnitude from each of them as described in the H. C. O. Annals, Volume XXVI, page 250. We can thus determine its brightness on from twenty to a hundred or more nights distributed over the last ten years. The approximate dates of maxima, the corresponding magnitudes, the period and the form of light curve are also determined so far as possible. Examples of such results have already been published, but every year, owing to the increasing amount of material, the work becomes more laborious although at the same time more complete and exact. Many of these stars vary irregularly so that their elements cannot be determined precisely. When the object is not a catalogue star its position, and that of each of the fainter comparison stars must also be determined from measures of their rectangular coordinates. An attempt is then made to photograph each of these variables once a month, and, if possible, to obtain corresponding observations of their visual magnitudes. As the total number of variable stars discovered here is now more than a hundred, not including those found in clusters, the labor involved in this work is very great. Accordingly, it is difficult to deduce all the required data for one star before another is found. The accompanying table gives the material that has been so far collected for the variables recently discovered here from the Draper Memorial photographs

CONSTELLATION.	DESIGNATION.	R. A.		Dec.	TYPE	No. PLATES.	MAGN.		DISCOVERER.
		1900.	1900.				Br.	Ft.	
		<i>h. m.</i>							
Eridanus . .	-16° 771	3 59.8	-16° 0'	III	35	8.3	9.4		M. Fleming.
Eridanus . .	-25° 1766	4 7.3	-25 24	III	65	8.1	<12.5		M. Fleming.
Monoceros . .	-8° 1641	6 52.5	-8 56	III	43	8.1	10.3		M. Fleming.
Puppis . . .	-38° 4019	8 1.7	-38 29	IV	..	..	..		L. D. Wells.
Puppis . . .	-22° 2160	8 3.1	-22 38	IV	..	..	..		L. D. Wells.
Hydra	-5° 2550	8 24.7	-5 59	III	..	..	..		M. Fleming.
Carina	R	10 40.9	-58 54	..	149	9.6	10.7		L. D. Wells.
Virgo	-5° 3424	12 2.1	-6 12	III	..	..	..		M. Fleming.
Centaurus . .		13 15.1	-61 3	III	..	..	..		M. Fleming.
Apus	A.G.C. 19014	13 55.6	-76 19	III	..	..	..		—
Boötes	+14° 2700	14 1.7	+13 59	III?	..	..	..		L. D. Wells.
Libra	-17° 4122	14 30.3	-17 36	II ?	38	8.3	9.6		E. F. Leland.
Triang. Aust.	A.G.C. 20554	15 4.8	-69 42	IV	85	9.1	9.8		—
Serpens . . .	+10° 2956	16 2.5	+10 12	III	41	9.0	<11.9		M. Fleming.
Ara	A.G.C. 23005	16 51.3	-51 55	IV	..	..	..		L. D. Wells.
Pavo	A.G.C. 23935	17 31.7	-57 40	IV	..	..	..		L. D. Wells.
Pavo		17 41.1	-62 23	III	65	9.1	<12.8		M. Fleming.
Ara		17 45.7	-51 40	III	..	..	..		M. Fleming.
Cygnus	+32° 3522	19 37.1	+32 23	IV	..	..	..		L. D. Wells.
Pavo	A.G.C. 27560	20 3.3	-60 14	III	..	..	..		M. Fleming.
Capricornus .	A.G.C. 27776	20 11.3	-21 38	IV	55	8.6	10.3		—
Microscopium	-40° 13888	20 22.6	-40 45	III	70	8.5	<12.5		M. Fleming.
Capricornus .	-17° 6181	21 1.7	-16 49	III	79	8.1	9.3		M. Fleming.
Aquarius . . .	-14° 5960	21 7.3	-14 48	III	78	8.4	9.3		M. Fleming.
Indus	A.G.C. 29232	21 13.6	-15 27	IV	..	..	..		L. D. Wells.
Andromeda . .	+47° 4318	23 50.3	+48 5	III	48	9.3	9.8		M. Fleming.
Cassiopeia . .		23 58.2	+55 7	III	101	9.8	<13.4		M. Fleming.

R. A. 3^h 59^m.8. Bright hydrogen lines suspected.

R. A. 4^h 7^m.3. Hydrogen lines bright.

R. A. 6^h 52^m.5. Hydrogen lines bright.

R. A. 8^h 1^m.7. Found to be fourth type by Mrs. Fleming.

R. A. 8^h 24^m.7. Bright hydrogen lines suspected.

R. A. 10^h 40^m.9. This star is No. 119 on page 627 of the Argentine General Catalogue.

R. A. 12^h 2^m.1. Bright hydrogen lines suspected.

R. A. 13^h 15^m.1. Hydrogen lines bright. The position of this star for 1875 is R.A. = 13^h 13^m 31^s, Dec. = -60° 55'.

R. A. 13^h 55^m.6. Bright hydrogen lines suspected. In the Uranometria Argentina, page 243, this star which is θ Apodis, is stated to be variable. Discovered

independently by Mrs. Fleming by means of its spectrum. The photographs show a variation of about one magnitude.

R. A. $15^h 4^m.8$. In Argentine General Catalogue "var?" Discovered independently from photographic charts by Miss L. D. Wells.

R. A. $16^h 2^m.5$. Hydrogen lines bright.

R. A. $17^h 41^m.1$. Hydrogen lines bright. The position of this star for 1875 is R. A. = $17^h 38^m 45^s$, Dec. = $-62^\circ 21'.6$.

R. A. $17^h 45^m.7$. Hydrogen lines bright. The position of this star for 1875 is R. A. = $17^h 43^m 42^s$, Dec. = $-51^\circ 39'.2$.

R. A. $20^h 3^m.3$. Bright hydrogen lines suspected.

R. A. $20^h 11^m.3$. Suspected of variability by Secchi and others. Found independently from the photographs by Miss L. D. Wells.

R. A. $20^h 22^m.6$. Hydrogen lines bright. Maxima represented by formula, $2410860 + 325 E$.

R. A. $23^h 50^m.3$. Bright hydrogen lines suspected.

R. A. $23^h 58^m.2$. Hydrogen lines bright. The position of this star for 1855 is R. A. = $23^h 55^m 53^s$, Dec. = $+54^\circ 52'.3$.

In Circular No. 10 the variability of $-27^\circ 15202$ (erroneously printed 15203) suspected by Thome was confirmed by Miss E. F. Leland. Measures of 35 photographs give the maximum brightness 8.9, minimum <12.3 .

In Circular No. 17 the variability of a star in R. A. = $0^h 25^m.6$, Dec. = $-46^\circ 58'$ (1900) is announced. Measures of 26 photographs give the maximum brightness 9.0, minimum <12.2 .

In Circular No. 17 the variability of a star in R. A. = $13^h 31^m.1$, Dec. = $-55^\circ 58'$ (1900) is announced. Measures of 42 photographs give the maximum brightness 9.0, minimum <12.6 .

In Circular No. 17 the variability of a star in R. A. = $20^h 8^m.5$, Dec. = $-44^\circ 43'$ (1900) is announced. Measures of 114 plates give the maximum brightness 9.0, minimum <11.4 .

In Circular No. 19 the variability of a star in R. A. = $5^h 18^m.9$, Dec. = $-69^\circ 21'$ (1900) is announced. Measures of 51 photographs give the maximum brightness 8.2, minimum 9.4.

EDWARD C. PICKERING.

January 31, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 25.

POLARIZING PHOTOMETERS.

Nearly all of the photometric measurements obtained at the Harvard College Observatory during the last twenty years have been made with modifications of three forms of photometers which are identical in principal. The first of these is described in the *Annals*, Vol. XI, Part I, and was used for the observations contained in that publication. The second, the meridian photometer, furnished the observations contained in the *Annals*, Volumes XIV, XXIII, XXIV, and XXXIV. The third photometer is described in the *Astrophysical Journal*, Vol. II, p. 89. In all of these instruments the star to be measured is compared directly with another star by means of a double image prism and Nicol. In the first instrument, the images of two adjacent stars are brought together by a double image prism; in the second, images of two stars however distant are brought together by reflecting them by prisms or mirrors into two object glasses; in the third photometer, images formed by a large telescope, of two stars not more than half a degree apart, are brought together by achromatic prisms.

An objection to the first form of photometer is that the emergent pencils of the images compared do not coincide. Small errors may therefore be introduced by irregularities in the cornea of the eye of the observer, or if he holds his eye in such a position that a portion of one image will be cut off by the edge of the pupil. This difficulty has recently been remedied by placing a second double image prism in the focal plane of the telescope, so that it does not affect the position of the two images but makes the emergent pencils coincide. A surprising degree of accuracy may then be obtained in the measures. Comparisons of the star α Ceti with the

adjacent star — $3^{\circ} 355$, which follows it about $10'$, have been made by Mr. O. C. Wendell with the 15 inch equatorial of this observatory, on 191 nights during the last five years. Until recently, the observations were made with the first form of photometer, the emergent pencils overlapping by about two fifths of their diameter. Generally thirty-two settings were made each night, and the mean of the differences of each pair of sets of four settings each on the first 14 nights of observation made during the present opposition was ± 0.074 magnitudes. On the last five nights the pencils were made to coincide, as just described, and the corresponding average differences were 0.020, 0.002, 0.025, 0.022, and 0.032, mean ± 0.020 . On the second of these nights, January 19, 1898, the eight measures of the difference in light of the two stars, each derived from four settings, were 4.48, 4.48, 4.48, 4.48, 4.48, 4.48, 4.48, and 4.47. Owing to variations in the transparency of the air in different parts of the sky, this degree of accordance can only be expected when stars near together are compared.

The accuracy of the results attainable with the third form of photometer is shown in the *Astrophysical Journ.* Vol. III, p. 281, and in the observations of U Pegasi described in Circular No. 23. Mr. Chandler (*Astron. Journ.* Vol. XVIII, p. 140) while admitting the principal conclusions given in that Circular, denies the reality of the small difference 0.15 between the primary and secondary minima. This quantity is so small that it doubtless could only be surely determined by the most accurate photometric measurements. The individual results derived from Mr. Wendell's observations are therefore given below. Twelve observations, each consisting of 16 settings were made when the star was within twenty minutes of its primary minimum. Deriving from each of these, by means of the light curve, the magnitude of this minimum we obtain on October 18, 1897, 9.89, 9.94, and 9.96; on December 30, 9.90, 9.95, and 9.93; on January 1, 1898, 9.93, 9.86, and 9.85; on January 5, 9.85, and on January 7, 9.86, and 9.88. Mean of all, 9.90, greatest value 9.96, least value 9.85, average deviation ± 0.035 . Similarly, fourteen observations were taken within twenty minutes of the secondary minimum with the results on October 18, 1897, 9.75, and 9.71; on October 29, 9.74, 9.69, 9.70, and 9.70; on December 28, 9.78, 9.77, 9.76, and 9.80; on January 3, 1898, 9.77, 9.77, 9.74, and 9.78. Mean of all, 9.75, greatest value 9.80, least value 9.69, average deviation ± 0.029 . It will be noticed that the largest value of the secondary minimum is 0.05

less than the smallest value of the primary minimum. If we assume that the primary and secondary minima are really equal, all of the first of these values give positive residuals with the mean value $+0.064$, and all of the second (with one exception $+0.01$) give negative values with the mean value -0.070 . The probability that the two minima are really equal and that these deviations are due to accidental error is extremely small. It is the same as that a person should draw a red card from a pack of cards twelve times in succession, and then should draw a black card thirteen times out of fourteen. On the other hand, if these deviations are due to a systematic error, it is very singular that this error always has one value at the time of a principal minimum, and another at the time of a secondary minimum.

EDWARD C. PICKERING.

February 8, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 26.

OCCULTATION OF 26 ARIETIS OBSERVED PHOTOGRAPHICALLY.

The disappearance of a bright star when occulted by the Moon is always a striking phenomenon. There is no celestial event whose time is susceptible of more precise determination. For many years various plans have been suggested, both here and elsewhere, by which this time could be determined with greater accuracy than by ordinary visual observation. In fact, the apparatus for photographing the eclipses of Jupiter's satellites, used here for several years, was devised in part for this purpose.

On February 25, 1898, Mr. Edward S. King for the first time succeeded in satisfactorily photographing the occultation of a star. The apparatus used was an improved form of that constructed for photographing the eclipses of Jupiter's satellites, and described in the *Astrophysical Journal*, Vol. I, p. 146. The plate was moved automatically every second by means of an electro-magnet. A motion of about 0.03 cm. was given to the plate whenever the circuit was closed, and of an equal amount when it was opened. Connecting the apparatus with the standard clock, Frodsham 1327, two images alternately faint and bright were obtained every second. As the faint images are three magnitudes fainter than the bright images, the ratio of the durations was about one to sixteen, so that the absolute durations were $0^s.06$ and $0^s.94$. It is here assumed that, as the times of exposure were very short, the chemical action was proportional to the time. This assumption is verified by actual measurement.

Considering only the images taken during the minute following $6^h 35^m 0^s$, the bright images of 26 Arietis, as shown below, are equally intense including that having an exposure lasting from $50^s.06$ to $51^s.00$. Since this image appears to be as

bright as the others, the light of the star could not have begun to diminish much before the time $51^s.00$. If the star had disappeared suddenly at $50^s.9$ the last image would be at least 0.12 of a magnitude fainter than the others, an amount readily measurable. The next image is apparently invisible. Had the disappearance taken place at $51^s.06$ the image would appear, and would be as bright as the other faint images. A slight darkening of the film is perceptible near the position the next image would have had, with an intensity nearly equal to that of the fainter images. If this were due to the star, it would denote that the latter suddenly disappeared at about $51^s.12$. The absence of the preceding image would indicate a more gradual disappearance. In any case, the time is fixed at $51^s.1$, to within one tenth of a second. As the clock was $2^m 19^s.4$ fast, not including armature time, the corresponding Greenwich Mean Time is $12^h 54^m 26^s.5$. By using shorter exposures the uncertainty in the time of disappearance can doubtless be greatly reduced, especially in the case of the brighter stars. Since satisfactory images of α Arietis, magnitude 6.1, were obtained in $0^s.06$, it is probable that occultations of stars as faint as the ninth magnitude can be observed photographically.

Measures were next made of the intensity of the last five images of α Arietis, to see if there was any diminution in light due to the absorption of a lunar atmosphere. The distances of these images from the Moon's limb were $1''.8$, $1''.4$, $1''.0$, $0''.6$, and $0''.2$, respectively. The corresponding changes in light, expressed in magnitudes as compared with ten more distant images, were $+0.03$, $+0.03$, -0.02 , $+0.03$, and -0.02 . A positive sign denotes that an image was fainter than those at a greater distance from the Moon. From this it appears that no diminution in light was perceptible. No correction need be applied to any of the above calculations for the diameter of the star's disc, since, assuming its intrinsic brightness equal to that of the Sun, its time of disappearance would be only $0^s.002$ (Proc. Amer. Acad. XVI, p. 1).

In this connection it is interesting to note that the determination photographically of the position of the Moon, by means of a star about to be occulted, was one of the subjects investigated by Professor G. P. Bond forty years ago. He obtained a number of photographs of the Moon and α Virginis shortly before the occultation of the latter on June 2, 1857.

EDWARD C. PICKERING.

March 3, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 27.

COMPARISON STARS FOR VARIABLES.

Applications have recently been received from several observers of variable stars for photometric magnitudes of the comparison stars used by them. The measurements described below are available and will be furnished in advance of publication to any astronomer who desires to use them. Sequences of comparison stars have been selected for about one hundred variable stars of long period. Examples of sixteen of these sequences will be found in the pamphlet entitled *Variable Stars of Long Period*, 4°, Cambridge, 1891. Each of the comparison stars brighter than the tenth magnitude has been measured on at least three nights with the meridian photometer. About five stars of each sequence, from the eleventh to the thirteenth magnitude, have been measured on two nights with the photometer having achromatic prisms. (*Astrophysical Journal*, Vol. II, p. 89.) The intervals between the adjacent stars in the sequences have been estimated in grades on three or more nights by Mr. Wendell with the fifteen inch telescope, and by Mr. Reed with the six inch telescope. From these estimates and measures, a system of magnitudes has been derived, in which the accidental errors are very small, and in which the scale for faint as well as for bright stars is nearly the same in all parts of the sky. This scale, which is that of the meridian photometer, is substantially the same as that of the Potsdam Observatory, and of the *Uranometria Oxoniensis*, the differences not exceeding one or two tenths of a magnitude. Observations are completed of the variable stars T Andromedae, T Cassiopeiae, R Andromedae, S Ceti, S Cassiopeiae, R Piscium, R Arietis, T Persei, α Ceti, S Persei, R Ceti, U Ceti, R Tauri, S Tauri, R Aurigae, U Orionis, R Lynceis, R Geminorum, S Canis Minoris, R Caneri, S Hydrae, T Hydrae, R Ursae Majoris, X Virginis, R Comae, T Virginis, Y Virginis, T Ursae Majoris, R Virginis, S Ursae Majoris, U Virginis, R Hydrae, S Bootis, R Camelopardali, U Herculis, W Herculis, R Ursae Minoris, R Draconis, χ Cygni, S Cygni.

R Delphini, U Cygni, V Cygni, T Aquarii, T Cephei, S Cephei, SS Cygni, S Aquarii, R Pegasi, S Pegasi, R Aquarii, and R Cassiopeiae, and it is expected that the others will be finished in a few months. An attempt is made at this Observatory to compare, by Argelander's method, the brightness of each of these variable stars once a month. If astronomers elsewhere would reduce their observations to the same scale of magnitudes a uniformity in results would be obtained which is now unfortunately lacking. These measures are now being extended to other variable stars of long period and it is hoped that later all stars of this class may be observed regularly and according to a uniform system.

Photometric magnitudes, determined with the meridian photometer, can also be furnished of many other stars brighter than the tenth magnitude, besides those mentioned above. Volumes XIV, XXIII, XXIV, and XXXIV of the *Annals* give the magnitudes of all stars from the North to the South Pole, brighter than the sixth magnitude, besides many fainter stars generally distributed in zones at regular intervals of five degrees in declination. Later observations have been made of all stars of the magnitude 7.5 and brighter, north of the declination -40° . A redetermination of the brightness of all the stars in the Harvard Photometry is included in this work.

MISCELLANEOUS NOTES.

The variability of a star in the constellation Aquila, whose position is in R. A. $19^h 33^m.3$, Dec. $+11^\circ 29'$ (1900), has recently been announced by the Rev. T. D. Anderson (*Astron. Nach.* **145**, 79.) Measures of 57 photographs give the maximum brightness 9.2, minimum <12.9 . The variations can be closely represented by the formula, $J. D. 2411550 + 330 E$.

The Rev. T. E. Espin, in Wolsingham Observatory Circular No. 45, calls attention to a red star of the eighth magnitude in R. A. $8^h 12^m 16^s$, Dec. $+32^\circ 19'$ (1855), not contained in the *Durchmusterung*. This star appears on 30 photographs taken from December 3, 1889 to March 5, 1898, and no variation in light exceeding two or three tenths of a magnitude is indicated. The individual results differ from their mean by ± 0.13 magn.

EDWARD C. PICKERING.

March 7, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 28.

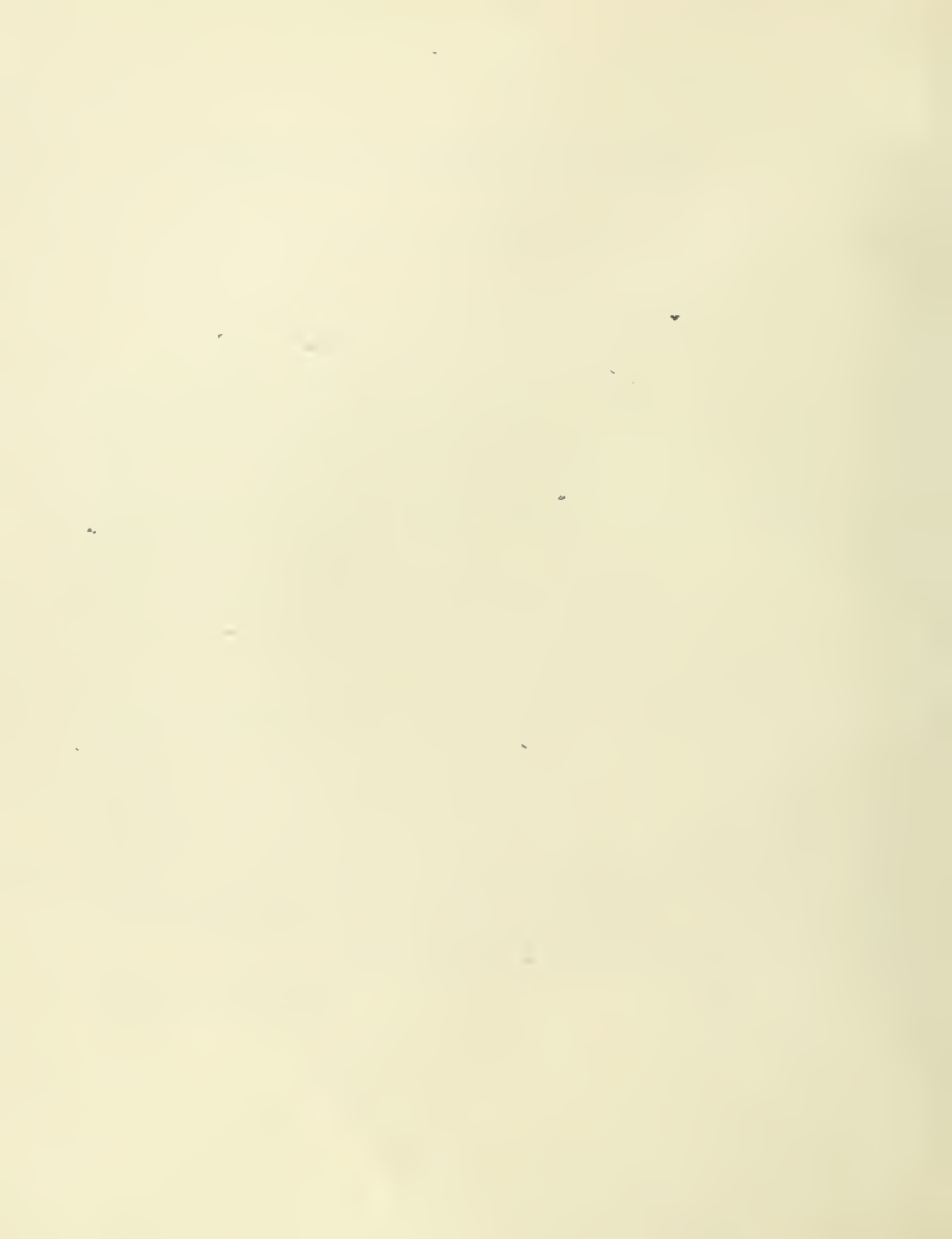
PHOTOGRAPHIC SPECTRUM OF THE AURORA.

Various attempts have been made at this Observatory to photograph the spectrum of the aurora. In 1886 on several occasions long exposures were given to plates during bright auroras but no result was obtained. On April 1, 1897, Mr. Edward S. King succeeded in obtaining a photograph in which four bright lines were visible, but uncertainty existed regarding their wave lengths. The exposure was 147 minutes. During the bright aurora of March 15, 1898, he obtained a photograph showing two bright lines. The exposure was 141 minutes. The brightest of these lines extends in wave length from about 3892 to 3925, and the wave length of the second is 4285. Assuming the two brighter lines photographed in 1897 to be identical with these, the four lines on that plate have the wave lengths 3862, 3922, 4288 and 4694. The first of these lines is very faint.

The errors of measurement of these lines do not exceed one or two units, but much greater uncertainty exists in the reduction owing to difficulties in comparing them with the lines of the solar spectrum which was photographed upon the same plate. Probably the two auroras gave different spectra. That in 1897 was taken with a wide slit but the images of the lines were well defined on the edges and of equal width, so that the line 3922 was probably really narrow and coincident with the edge of greater wave length of the line 3892 to 3925. The spectroscope used was not especially designed for photographing faint surfaces and it is hoped that better results may be obtained with a new instrument now in course of construction. As is the case with all results announced in these Circulars it is expected that full details will be published later in the Annals of the Observatory.

EDWARD C. PICKERING.

March 23, 1898.



HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 29.

VARIABLE STARS OF SHORT PERIOD.

Whoever will make a careful examination of the brightness of a large number of stars either in the sky, or better as photographed upon different plates, will be impressed with the vast number which show no perceptible variation. The discovery of variable stars is greatly aided when we are able to make a suitable selection for examination, either from their spectra or from their presence in clusters. Visually, we can never be sure that all the variables in a given region have been found, however carefully we may study them. Photography brings this problem more nearly within our reach, and a partial solution of it is illustrated in the accompanying figure. A photographic telescope was constructed having as an objective a Cooke Anastigmatic Lens with an aperture of 2.6 cm. and a focal length of 33.3 cm. This telescope was mounted equatorially and the lens was alternately exposed and covered for intervals of exactly 10 and 50 minutes by an electrical attachment. The polar axis of the mounting was displaced and the rate of the driving clock was increased, so that the successive images should be slightly separated. An 8×10 photographic plate was exposed in this instrument on April 21,



1898, and eight successive images were obtained, the Greenwich Mean Times of the middle of the exposures being $13^h 49^m$, $14^h 49^m$, $15^h 49^m$, $16^h 49^m$, $17^h 49^m$, $18^h 48^m$, $19^h 48^m$, and $20^h 48^m$. The plate covered a region about $33'$ square, whose

centre was R.A. = $1^h 2^m$, Dec. = $+76^\circ 6'$. The images of the stars in the corners of the plate were sufficiently good when visible to show very slight variations in light, but owing to their increased size the faintest stars were not shown. The greatest loss amounted to about one magnitude. If now any variable star having a period of less than 14 hours was contained in this region it is probable that at least one maximum and one minimum would be photographed. The figure represents a portion of the plate described above, enlarged ten times to a scale of $60'' = 0.1$ cm., and covers about one square degree. It therefore represents one thousandth of the entire plate, the size of which on this scale would be two meters, or nearly seven feet square. The entire sky, from the north to the south pole, could be covered by forty such plates, and it is proposed to do this as soon as the best method of taking the plates has been determined. The arrow indicates the variable star U Cephei, and its photometric magnitudes at the times the eight images were taken were 7.5, 8.1, 8.9, 9.1, 9.1, 8.3, 7.6, and 7.2. The three stars above it are $+81^\circ 30'$, $+81^\circ 27'$, and $+81^\circ 29'$, which have the photometric magnitudes 7.9, 8.5, and 8.6. To separate the successive images various methods have been tried. The best of these seems to be stopping the driving clock for a few seconds every hour. By the above plan we hope to secure a complete list of all variable stars of short period brighter than the ninth magnitude at maximum whose variation exceeds half a magnitude and whose period is less than a day. Doubtless, many other variable stars of longer period, and stars of the Algol type may also be incidentally found.

EDWARD C. PICKERING.

May 21, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 30.

THE SUPPOSED VARIABLE STAR, γ AQUILAE.

Measures to determine the light curves of variable stars of short period, north of declination -40° , are now in progress with the meridian photometer. Four sets of four settings each are ordinarily made when the star to be observed is about half an hour east of the meridian, and again about an hour later. These measures are repeated on twenty or thirty nights. The principal error is that due to the unequal transparency of the air in different portions of the sky, the stars compared being often far apart. The accidental errors of measurement are small owing to the number of settings. Smooth light curves have been found for all the stars thus measured, with the exception of $+10^\circ 3787$. The designation γ Aquilae was given to this star by Mr. S. C. Chandler, and in his catalogue of variable stars he states that it varies from magnitude 5.3 to 5.7 in a period of 4.986 days. Also, that it was "Susp. by Gould, confirmed by Chandler, 1894; also by Yendell." It will be noticed that the period is so nearly five days, that for several months the same phase will recur at about the same hour angle, thus permitting errors to occur in visual observations by Argelander's method, such as are mentioned in Circular No. 23, and which led to such wholly erroneous conclusions in the case of ι Pegasi.

The star $+10^\circ 3787$ was observed with the meridian photometer on nineteen nights, from August 25 to October 13, 1897. Placing together the observations having the same phase we find, corresponding to the phases $0^h.0$, $1^h.0$, $2^h.0$, $3^h.0$, and $4^h.0$, the mean residuals -0.09 , 0.00 , $+0.02$, $+0.02$, and $+0.03$. We might infer a variation

with a range of a tenth of a magnitude, but the first value, -0.09 , depends on observations on a single night, and the range of the other four is only 0.03 . This star is No. 39, of the standards selected by the observers at Potsdam, and they state that from their observations, they find no confirmation of the variation suspected by Dr. Gould. Mr. Chandler, however (*Astron. Journ.* XIV, 135) states that these observations, 57 in number, confirm the period of variation that he has found, although indicating that the range of variation is less. A reduction of these observations made here, however, leads to the same conclusion as that found at Potsdam. The actual number of observations of this star made at Potsdam appears to be 75, not 57, 49 of them in determining the light of the standards, and 26 in the supplementary zones. Grouping them according to phase, we obtain the residuals -0.07 , -0.02 , $+0.01$, 0.00 , and -0.16 , corresponding to the phases $0^d.6$, $1^d.6$, $2^d.6$, $3^d.6$, and $4^d.6$. The last residual is reduced to -0.12 if we reject the observations on one night, and to -0.09 , if we reject those made on two nights and use only the observations from which the light of the fundamental stars was determined. To decide whether such residuals as these are due to accident, the Potsdam observations were again grouped assuming a period of six days instead of five. The mean residuals corresponding to the phases 0, 1, 2, 3, 4, and 5 days then become -0.03 , -0.19 , -0.14 , -0.02 , $+0.01$, and 0.00 . The preponderance of negative residuals is caused by the supplementary observations which indicate that the star was slightly brighter than when the standards were originally measured. Grouping the observations with the meridian photometer in the same way, we obtain the mean residuals 0.00 , 0.00 , -0.07 , -0.02 , -0.02 , and $+0.07$. In both cases, therefore, a period taken at random indicates variability more clearly than that hitherto assumed. Mr. Yendell (*Astron. Journ.* XIV, 160), confirms visually the variability of this star.

The accuracy of the observations described in Circulars Nos. 23 and 25, seems to afford a conclusive test of the variability of this star. Accordingly, comparisons were made by Mr. Wendell with the photometer attached to the 15 inch equatorial telescope on May 9, 10, 13, 14, 21, and 22, 1898. Eighty settings were made each night. The comparison star was $+10^{\circ}$ 3784. The mean differences of magnitude were 3.63, 3.64, 3.66, 3.66, 3.66, and 3.62, and the average deviations from their means, of the five groups of sixteen settings each on the different nights, were ± 0.022 , ± 0.028 , ± 0.020 , ± 0.012 , ± 0.030 , and ± 0.012 . The first and fourth nights have nearly the same phase,

0^h.8. Combining these in one group, and placing the others in the order of phase, we have the phases, 0^h.8, 1^h.8, 2^h.8, 3^h.9, and 4^h.8, and the corresponding residuals, 0.00, 0.00, -0.02, +0.02, and -0.02. A positive residual, as usual, denotes that the star was faint. The average value of these residuals is ± 0.012 , and the range 0.04.

The three series of photometric observations discussed above, therefore, fail to show any evidence of variation, since deviations of a tenth of a magnitude, except in the last series of measures, may be ascribed to errors of observation. Since it is impossible to prove that the light of a star never changes, this star may still be an Algol variable with a short time of variation, or the period may be entirely wrong.

EDWARD C. PICKERING.

May 25, 1898.

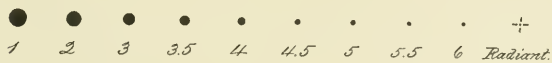
HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 31.

THE NOVEMBER METEORS.

On the night of November 13, 1897, 91 meteors were observed at the Harvard College Observatory, and 47 meteors at an auxiliary station 12 miles south, the Blue Hill Meteorological Observatory. A discussion of these observations by Professor W. H. Pickering will be found in the Annals of this Observatory, Volume XLI., No. V. A much greater display of meteors is expected next year, and it is very important that a continuous watch should be kept during the two or three days in which the Earth is passing through the denser portion of the meteor stream. This can only be done by establishing a series of stations in various longitudes, so that during the entire time one or more of these stations shall fulfil the conditions that the radiant point shall be above the horizon and the Sun below. Correspondence is invited with astronomers and others willing to participate in this work, especially with those who will be in the less frequented longitudes. If the weather is favorable, and the plan here proposed is carried out satisfactorily, it is expected that all the observations will be discussed here, and published in the Annals of this Observatory. To secure the best results a uniform plan of work is essential. Maps and forms of record will be sent to all who early signify their readiness to take part in this work. The radiant point of the meteors indicated by the cross in the accompanying map, will not rise in this latitude until $10^h\ 30^m$, and twilight will interfere at about $5^h\ 30^m$ in the morning. As the shower sometimes begins before the predicted date, a watch should be kept on November 11 and 12, from 11 to 1 o'clock, and if many meteors are seen the observations described below, for November 13, should be made on these nights, and also on the nights following the shower.

Each observer is requested to devote his attention to the region within 25° of the radiant point, and included in the map, and to send the following data regarding his



observations:—Name of observer, location of station, post office address, time of beginning and ending of observations, interruptions by clouds or other causes, condition of sky, as clear, hazy, passing clouds, etc.

The observations most desired are those required to determine the frequency of the meteors. They are of extreme simplicity and need only care, system, and perseverance. Once an hour, or better once every half hour, observe and record the time during which ten meteors appear. This is most easily done by noting the time by a watch and at exactly the beginning of a minute looking at the sky, giving it undivided attention and counting the meteors seen, not including those appearing outside of the region covered by the map. If great numbers of meteors appear it may be better to count a larger number, as twenty or even fifty. If the interval between the meteors is long, the number to be counted may be reduced. These observations should be repeated until dawn, or over as long an interval as possible. Between these observations the observer may rest, or may make special observations of individual meteors. Thus, when a meteor is seen, record the hour and minute, the brightness on a scale of stellar magnitudes,—2, equals the brightness of Jupiter or Sirius; 0, Arcturus or Vega; 2, the Pole Star; 4, the Pleiades; 6, the faintest star visible: the color, B = blue, G = green, Y = yellow, W = white, and R = red; the class, L = Leonid, if path prolonged would pass through centre of map, N = other meteors. Thus L 5 Y, 12^h 26^m, indicates that a Leonid, magnitude 5, yellow in color, was seen at 12^h 26^m. Find by trial beforehand how many seconds are required to make each record. Again, the path of each meteor may be marked upon the map by noting its position in relation to the adjacent stars. Such work can be done equally well elsewhere, and should not interfere with the hourly count mentioned above.

EDWARD C. PICKERING.

May 30, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 32.

STARS HAVING PECULIAR SPECTRA.

A list of stars having peculiar spectra is given in the annexed table. With one exception, noted below, they were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial photographs. The designation of the star, its approximate right ascension and declination for 1900, its catalogue magnitude, and a brief description of its photographic spectrum are given in the successive columns of the table. When the object is not a catalogue star its position, as derived from a photograph, is given in the notes following the table.

DESIGNATION.	R. A. 1900.	DEC. 1900.	MAGN.	DESCRIPTION.
	<i>h m</i>			
.	0 54.2	— 75° 32'	. .	Type III. Hydrogen lines bright. Variable.
+ 11° 305 .	2 9.6	+ 11 47	8.9	Type IV.
A. G. C. 4042	3 35.2	— 55 43	8.2	Type III. Hydrogen lines bright? Variable.
.	4 52.0	— 67 6	. .	Gaseous nebula. Gal. long. 244° 36', lat. — 36° 03'.
Z. C. 5 ^a 418	5 12.3	— 47 2	8.5	Type III. Hydrogen lines bright. Variable.
— 12° 1453	6 17.1	— 12 56	9.6	Gaseous nebula. Gal. long. 188° 54', lat. — 11° 01'.
— 12° 1500	6 23.7	— 12 59	7.7	Type I. H β bright.
+ 5° 1267	6 25.2	+ 5 57	7.1	Type I. H β bright.
— 8° 1467	6 28.1	— 8 48	8.5	Peculiar. Variable with small range.
+ 6° 1309	6 32.0	+ 6 14	6.5	Type I. H β bright. H. P. 1250.
.	7 13.9	— 13 3	. .	Type V. Gal. long. 195° 30', lat. + 1° 11'.
— 3° 1873	7 18.1	— 4 0	9.2	Type IV.
— 11° 1941	7 22.4	— 11 31	8.9	Peculiar. Variable.
— 17° 2442	8 15.2	— 17 57	9.1	Type IV.
.	9 6.1	— 69 32	. .	Gaseous nebula. Gal. long. 253° 06', lat. — 14° 50'.
.	9 13.5	— 65 49	. .	Type IV. Variable.
+ 60° 1246	10 8.3	+ 60 31	6.3	Type III. Peculiar. Variable.
A. G. C. 14145	10 17.2	— 55 33	5	Type I. H β and H γ bright. J Velorum.
A. G. C. 14686	10 49.1	— 59 1	7	Type I. H β bright.
.	10 42.6	— 65 5	. .	Type IV.
Z. C. 11 ^a 129	11 2.9	— 54 35	9	Type IV.
.	11 55.3	— 54 33	. .	Type IV.
— 4° 3199	11 59.6	— 5 13	8.7	Type II. Variable.
.	13 26.8	— 61 48	. .	Type V. Gal. long. 275° 30', lat. — 0° 18'.
.	13 29.1	— 61 45	. .	Type V. Gal. long. 275° 46', lat. — 0° 18'.
.	15 26.7	— 71 34	. .	Type I. H β , H γ , H δ , H ϵ , and H ζ bright.
Z. C. 18 ^a 1935	18 35.2	— 51 51	9	Type IV.
.	19 47.0	— 65 37	. .	Peculiar.
.	21 36.6	— 65 30	. .	Type IV.
— 8° 5858	22 16.5	— 8 7	8.5	Type III. Hydrogen lines bright? Variable.

$0^h 54^m.2$. Position for 1875, R.A. = $0^h 53^m 22^s.4$, Dec. = $-75^\circ 46' 30''$.

$4^h 52^m.0$. Position for 1875, R.A. = $4^h 52^m 1^s.2$, Dec. = $-67^\circ 7' 39''$. This object is N.G.C. 1714.

$7^h 13^m.9$. Position for 1855, R.A. = $7^h 11^m 45^s.4$, Dec. = $-12^\circ 58' 2''$.

$7^h 18^m.1$. In the *Astron. Nach.* Vol. 118, p. 259, Espin gives $-3^\circ 1886$, magn. 8.7, as having a spectrum of the fourth type. $-3^\circ 1886$ follows $-3^\circ 1873 1^m.8$ south $0'.3$, and has a spectrum of the first type. Probably $-3^\circ 1873$ was the object observed by Espin but erroneously identified by him.

$7^h 22^m.4$. The spectrum of this star resembles that of a star of the fourth type. The bands, however, are of shorter wave length, and are, perhaps, identical with those of a star of the third type. The portion of the spectrum whose wave length is less than H γ , 4341, is too faint to appear in the photographs.

$9^h 6^m.1$. Position for 1875, R.A. = $9^h 5^m 50^s.3$, Dec. = $-69^\circ 25' 58''$.

$9^h 13^m.5$. Position for 1875, R.A. = $9^h 12^m 59^s.8$, Dec. = $-65^\circ 42' 37''$.

$10^h 17^m.2$. The lines H β and H γ in this star have been found to be variable by Miss A. J. Cannon. On June 2, 1893, they were bright, and superposed on a broad dark band. On April 17, 1895, and March 17, 1896, these lines, like the other hydrogen lines, were dark.

$10^h 40^m.1$. The hydrogen lines in this star appear to be variable. On May 20, 1892, H β , H γ , and H δ were dark. On April 3, 1895, the line H β was bright. On April 21, 1895, H β and H γ were bright. H ζ and H η were dark, with the edge of greater wave length apparently bright.

$10^h 42^m.6$. Position for 1875, R.A. = $10^h 41^m 40^s.8$, Dec. = $-64^\circ 57' 20''$.

$11^h 55^m.3$. Position for 1875, R.A. = $11^h 54^m 3^s.1$, Dec. = $-54^\circ 25' 24''$.

$13^h 26^m.8$. Position for 1875, R.A. = $13^h 25^m 6^s.2$, Dec. = $-61^\circ 40' 30''$.

$13^h 29^m.1$. Position for 1875, R.A. = $13^h 27^m 23^s.2$, Dec. = $-61^\circ 37' 4''$.

$15^h 26^m.7$. Position for 1875, R.A. = $15^h 24^m 8^s.2$, Dec. = $-71^\circ 29' 26''$. This is the object whose position for 1900 is announced in *Astronomy and Astrophysics*, Vol. 12, p. 546, as R.A. = $15^h 27^m.0$, Dec. = $-71^\circ 32'$. Its spectrum is there described as of the third type having also bright hydrogen lines, and consequently it was suspected of variability. Later and better photographs show that the spectrum is continuous, with the hydrogen lines H β , H γ , H δ , H ϵ , and H ζ bright, resembling that of η Carinae as seen with the same dispersion. The variability is not confirmed.

$19^h 47^m.0$. Position for 1875, R. A. = $19^h 44^m 37^s.0$, Dec. = $-65^\circ 41' 9''$.

$21^h 36^m.6$. Position for 1875, R. A. = $21^h 34^m 37^s.9$, Dec. = $-65^\circ 37' 28''$.

STARS RESEMBLING ζ PUPPIS.

Besides ζ Puppis, the additional lines due to hydrogen are present in the spectra of the first and second classes of stars of the fifth type (Astron. Nach. Vol. 127, p. 1), and in the spectra of the first group of stars of the Orion type according to the classification of Miss Maury (H. C. O. Annals, XXVIII, p. 15). The lines whose wave lengths are there given as 4200.3, 4542.7, are probably additional hydrogen lines, and the line 4685.4 probably coincides with the bright band in ζ Puppis. Miss A. J. Cannon, from a careful study of the Draper Memorial photographs of the bright southern stars, has added the following stars to those already known to contain these lines. In A. G. C. 17572 the lines 3925, 4027, 4202, and 4544 are present and dark. In the fifth type stars, A. G. C. 8631 and 22763, the lines 4027, 4202, and 4544, and the bands 4633 and 4688 are present and bright. In the fifth type stars, A. G. C. 10863 22748, and 22843, the hydrogen lines 3925, 4027, 4202, and 4544 are present and dark, and the bands 4633 and 4688 are present and bright. The band 4633 is double in the last two stars, and also in A. G. C. 9311, 29 Canis Majoris.

EDWARD C. PICKERING.

June 21, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 33.

VARIABLE STARS IN CLUSTERS.

The discovery, by Professor S. I. Bailey, of the presence of large numbers of variable stars in certain globular clusters has already been announced in Circulars Nos. 2 and 18. A systematic search for such variable stars has been made by Professor Bailey and has led to the results given below. In the following table the first column gives the number in the New General Catalogue of Dreyer; the second, the Messier number, or in certain cases some other designation; the third and fourth columns the position for 1900; the fifth column the approximate number of stars examined; the sixth, the number of plates used in the examination. In the case of certain clusters later investigations have included more plates. The seventh column gives the area, always a circle having for its centre the centre of the cluster, included in the examination. The eighth column gives the number of variable stars found; the ninth, the maximum distance of any variable from the centre of the cluster. In N. G. C. 7078 this distance is given as $7'$, since a circle having a radius of $7'$ includes 50 variables. One variable, perhaps not related to the others, is found at a distance of $10'$. The tenth column gives the area of a circle of sufficient radius to include all the variables. The eleventh column gives the proportion of variables to the whole number of stars examined; the twelfth, the number of stars to one variable.

As will be seen by reference to the table, the whole number of stars examined is 19050, of which 509 are variable. This amounts to one variable in 37 stars or nearly 3 per cent. It does not follow however that clusters in general contain more variable stars than occur elsewhere, for, if we except the four clusters, ω Centauri, Messier 3, Messier 5, and Messier 15, which together contain 393 variables, an average of 7 per cent, the remaining 19 clusters have 116 variables among 13350 stars, or less than one per cent. There is a very striking difference between the results obtained in clusters equally rich in stars, as for example, between Messier 13, the great cluster in Hercules, where an examination of 1000 stars shows two variables, one in 500; and Messier 3, where among 900 stars, 132 are variable, one in 7. A common plane of revolution, orbital or axial, of the different systems or individuals of star clusters,

VARIABLE STARS IN CLUSTERS.

Designation		Position, 1900.		No. stars examined.	No. plates examined.	Area examined.	No. variables found.	Maximum distance.	Area of variables.	Proportion of variables.	No. of stars to one var.
		R. A.	Dec								
		<i>h.</i>	<i>m</i>			Sq. Min.	<i>h</i>	<i>m</i>	Sq. Min.		
101	47 Tucanae	0 19.6	-72 38	2000	10	1257	6	6	113	.003	333
362		0 58.9	-71 23	675	10	314	14	9	254	.021	48
809		2 12.0	+56 11)	1050	10	10800	1	—	—	.001	1050
884		2 15.4	+56 39)								
1904	Messier 79	5 20.1	-24 37	200	6	79	5	3.5	38	.025	40
3293		10 29.6	-57 40	724	10	314	0	—	—	.000	—
4755	κ Crucis	12 47.7	-59 48	555	10	314	0	—	—	.000	—
5139	ω Centauri	13 20.8	-46 47	3000	10	1257	125	22	1521	.042	24
5272	Messier 3	13 37.6	+28 53	900	10	1257	132	17	908	.147	7
5904	Messier 5	15 13.5	+ 2 27	900	10	1257	85	17	908	.094	11
5986		15 39.5	-37 26	289	12	314	1	1.7	—	.003	289
6093	Messier 80	16 11.1	-22 44	145	5	79	2	2.5	20	.014	72
6205	Messier 13	16 38.4	+36 39	1000	10	177	2	1.3	5	.002	500
6266	Messier 62	16 54.9	-29 58	960	10	218	26	8	201	.027	37
6397		17 32.5	-53 37	487	5	218	2	7.5	177	.004	244
6626	Messier 28	18 18.4	-24 55	900	9	314	9	7	154	.010	100
6656	Messier 22	18 30.3	-23 59	1550	10	218	16	8	201	.010	97
6723		18 52.8	-36 46	900	6	314	16	4.5	64	.018	56
6752		19 2.0	-60 8	600	8	218	1	4	—	.002	600
6809	Messier 55	19 33.7	-31 10	440	6	218	2	5	79	.005	220
7078	Messier 15	21 25.2	+14 44	900	10	1257	51	7	154	.057	18
7089	Messier 2	21 28.3	- 1 16	600	10	218	10	4	50	.017	60
7099	Messier 30	21 34.7	-23 38	275	10	218	3	2.5	20	.011	92
				19050		20830	509		4867		

and the relation of that plane to the line of sight, might provisionally be suggested as a possible explanation.

The periods and light curves of several variables in other clusters have been determined, but the study of those in ω Centauri is well advanced. This cluster may be called the finest in the sky. It lies just within the border of the Milky Way. There are no bright stars near. To the naked eye it appears as a hazy star of the fourth magnitude. It has a diameter of about 40'. The brightest individual stars in this region are between the eighth and ninth magnitude. Over 6000 stars have been counted on one of the photographs, and the whole number is much greater. Only about 3000, however, are sufficiently bright and well separated to serve for comparison in the discovery of variables. Of these 3000, 125 are variable. 150 photographs of the cluster have been taken with the 13" telescope and already 10000 measures have been obtained, about half of which have been made by Miss E. F. Leland.

Although the results are at present provisional, it is not probable that the final results of the discussion will materially alter the conclusions. Of the 106 variables in ω Centauri whose periods have been determined, 98 have periods less than 24^h . The longest period is that of No. 2, 475^d , the shortest that of No. 91, $6^h 11^m$. Three have periods less than 7^h . Of the eight having periods of more than 24^h , two have periods between one and two days, two between two and three days, one of 4 days, one of 15 days, one of 150 days, and one of 475 days.

The largest range in variation is about five magnitudes, and no star has been included whose light changes do not amount to half a magnitude.

The light curves of the 98 stars whose periods are less than 24 hours may be divided into four classes. The first is well represented by No. 74. The period of this star is $12^h 4^m.3$, and the range in brightness, two magnitudes. Probably the change in brightness is continuous. The increase of light is very rapid, occupying not more than one fifth of the whole period. In some cases, possibly in this star, the light remains constant for a short time at minimum. In most cases, however, the change in brightness seems to be continuous. The simple type shown by No. 74 is more prevalent in this cluster than any other. There are, nevertheless, several stars, as No. 7, where there is a more or less well marked secondary maximum. The period of this star is $2^d 11^h 51^m$, and the range in brightness, one and a half magnitudes. The light curve is similar to that of well known short-period variables, as δ Cephei and η Aquilae. Another class may be represented by No. 126, in which the range is less than a magnitude, and the times of increase and decrease are about equal. The period is $8^h 12^m.3$. No. 24 may perhaps be referred to as a fourth type. The range is about seven tenths of a magnitude, and the period is $11^h 5^m.7$. Apparently about 65 per cent of the whole period is occupied by the increase of the light. This very slow rate of increase is especially striking from the fact that in many cases in this cluster the increase is extremely rapid, probably not more than ten per cent of the whole period. In one case, No. 45, having a period of $14^h 8^m$, the rise from minimum to maximum, a change of two magnitudes, takes place in about one hour and in certain cases, chiefly owing to the necessary duration of a photographic exposure, there is no proof at present that the rise is not much more rapid.

The marked regularity in the period of these stars is worthy of attention. Several have been studied during more than a thousand, and one during more than five thousand periods, without irregularities manifesting themselves.

A few words may be added in regard to the kind of clusters in which variables have been found. Up to the present time they have not been found in any except dense globular clusters, of which Messier 3, Messier 5, and the great cluster in Hercules may be taken as examples. The number of such clusters within the reach of ordinary instruments is not great. Of the clusters given in the table N. G. C. 104, 362, 5139, 5272, 5904, 6093, 6205, 6266, 6626, 7078, and 7089 may be described as highly condensed: 1904, 5986, 6397, 6656, 6723, 6752, 6809 and 7099 as moderately condensed; and 3293 and 4755 as open clusters. 869 and 884, the clusters in the Sword-handle of Perseus are little more than regions relatively rich in stars.

The first group of 11 highly condensed clusters having a total of 11980 stars has 462 variables, or one in 26. The second group of 8 moderately condensed clusters has 46 variables among 4741 stars, one in 103. The two open clusters furnished no variables, and the region of three square degrees around N. G. C. 869 and 884, only one.

Thus far the only regions which are found to be especially rich in variable stars are condensed clusters, but even here only in relatively few cases. These dense clusters are commonly called globular, and many of them are such. In some cases however, as ω Centauri, the form is somewhat elliptical.

N. G. C. 6266 is the most striking example of a highly condensed cluster which is irregular in form. This irregularity is intensified in the distribution of the variables. The cluster is much compressed on the south side. For a distance of 1' from the centre the distribution of the stars seems to be about equal, but if a line be drawn east and west through the centre, and the stars within 1' of this line are omitted, there are 214 stars south, and 354 stars north, within 4' of the central line. In this cluster are 26 variables, of which 19 are north of the central line and 7 south. Excluding those within 70'', there are 15 north and only 1 south.

EDWARD C. PICKERING.

September 17, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 34.

WITT'S PLANET D Q.

One of the most important astronomical discoveries of recent years is the finding of the planet D Q, by Witt. This object will come nearer to the Earth than any other similar object, except the Moon. Its minimum distance is about 15 million miles, and the corresponding parallax nearly a minute of arc. To determine the photometric brightness of this object, the stars, $-6^{\circ}5567$, $-6^{\circ}5579$, $-6^{\circ}5600$, $-6^{\circ}5608$, and $-6^{\circ}5626$ were each measured on five nights with the meridian photometer, eight settings being made each night, with the resulting magnitudes, 7.87, 8.65, 8.71, 8.56, and 9.57, respectively. The probable error of these values varies from ± 0.020 to ± 0.033 . The brightness of the stars, $-6^{\circ}5550$, $-6^{\circ}5560$, and $-6^{\circ}5588$ was later determined differentially from these, with the resulting magnitudes 8.80, 9.89, and 8.37. Mr. Wendell compared the planet on six nights by means of the photometer with achromatic prisms attached to the 15-inch equatorial. The number of settings on each night was 48. On September 5 and 6, 1898, it was compared with $-6^{\circ}5626$, on September 9 with $-6^{\circ}5608$, on September 12 with $-6^{\circ}5579$, and on September 13 and 14 with $-6^{\circ}5588$. The resulting magnitudes were 12.19, 11.97, 12.10, 12.01, 12.20, and 12.29. Mean, 12.13 ± 0.04 . As the logarithms of the distances of the Sun and Earth, on the mean date, September 10, were 0.2366 and 9.9115, the magnitude when these distances are both unity becomes 11.39.

It is not easy to obtain photographs adapted to determining the photographic brightness of this object, owing to its faintness and rapid motion. With a short exposure the image is very faint, and with a long exposure a trail is obtained which cannot be compared with the circular images of adjacent stars. Measures of the

photographic brightness have been made by Mrs. Fleming on plates taken with the 8 inch Draper telescope, and having exposures of about 15 minutes. The planet was not far distant from the variable star T Aquarii and was compared with four of its comparison stars whose photometric magnitudes had already been determined. Plates taken on September 6, 12, 13, 13, 13, 14, 17, 20, and 21, 1898, gave the magnitudes 12.78, 12.75, 12.80, 12.85, 12.78, 12.75, 12.75, 12.72, 12.65, and 12.68. Mean, 12.75 ± 0.01 . Similar measures of two isochromatic plates taken on September 17 and 20 gave the magnitudes 12.80 and 12.61. Mean, $12.70, \pm 0.08$. Since the planet is fainter photographically than photometrically, it is probable that its color, like that of the Sun, is redder than an average star.

Several interesting photometric problems present themselves in connection with this object. First, the approximate diameter may be determined by comparison with the brighter asteroids and satellites, assuming that the reflecting power is the same. Secondly, the great variation in the distance of this object from the Earth will afford an excellent test of the law that the light varies inversely as the square of the distance. The existence of an absorbing medium in the solar system will thus be tested. Thirdly, owing to the proximity of this object to the Earth at opposition, its phase angle will vary by a large amount. It will, therefore, afford an excellent test of the law connecting this angle with the variation in brightness, which has been found by two or three observers independently.

NEBULA IN ANDROMEDA.

A comparison of photographs of the Nebula in Andromeda taken with the 8 inch and 11 inch Draper telescopes on September 20 and 21, 1898, with similar photographs taken in 1893, 1894, 1895 and 1896 fails to show the new stellated appearance recently announced by Seraphimoff of Pulkowa. See also *Astron. Nach.* 147, p. 223.

EDWARD C. PICKERING.

September 30, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 35.

THE NOVEMBER METEORS IN 1898.

Observations of the Meteoric Shower of November 13, 1897, were made at the Harvard College Observatory, and a description of the results will be found in the *Annals*, Vol. XLI, No. 5, and in Circular No. 31. More extensive observations were made in 1898, and the results will be published later in the *Annals*. Several investigations were undertaken, and some of the preliminary results are given below. As proposed in Circular No. 31, stations have been selected all around the Earth in order that counts of the number of meteors visible might be made during the entire time that the Earth traversed the meteor stream. The density of different portions of the stream would thus be determined. Reports from the distant stations will not be received for some time. The night of November 13 was cloudy in Cambridge, but on November 14, 800 meteors, not including duplicates, were recorded at this Observatory by 30 persons. The maximum occurred at three o'clock in the morning, when 61 meteors east of the meridian were counted in half an hour. 227 trails of 80 different meteors, within 30° of the radiant point, were charted. Similar observations were made at Providence by Professor Upton of the Ladd Observatory, aided by a number of students. The vicinity of the radiant was watched continuously by at least ten observers, who recorded 400 meteors. This station is 40 miles south of Cambridge, and was selected as suitable for determining the parallax visually. Ninety-six photographs were taken at Cambridge with the Draper telescopes and with eleven smaller instruments. Five photographic doublets were mounted equatorially and photographed the region within 30° of the radiant, during nearly the entire night. Two cameras were carried to Tufts College, two miles north of Cambridge, and twenty-five

photographs were taken simultaneously at both stations for a photographic determination of the parallax. In all, 31 trails of eight different meteors were photographed, of which 3 appeared on one plate. Four meteors were photographed at both stations, and can be used for determining the parallax photographically. The changing distance of the meteors is obvious by inspection of these photographs. A preliminary determination of the radiant was made by prolonging the trails of 4 meteors. They nearly intersect in a point, the greatest deviation not exceeding 1 mm., or 10'. The position of the radiant reduced to 1900 is thus given as R. A. = $10^h 6^m$. S. Dec. = $+22^\circ 16'$, which is 9^m following, and $38'$ south of the place given by Denning. Seventeen plates were taken with prisms, but they failed to show the spectra of any meteors. It appears from the photographs that the light of the meteors attained a maximum and then diminished as rapidly as it increased. In some cases, sudden changes due to explosions are well shown. The trail is sometimes surrounded by a sheath of light, and in one case the trail remaining after the meteor had passed was photographed. These results show that meteoric showers may now be studied to advantage by photography.

EDWARD C. PICKERING.

November 19, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 36.

WITT'S PLANET, (433) D Q.

A careful search has been made by Mrs. Fleming upon the Harvard plates for early photographs of Witt's Planet, (433) D Q. Mr. S. C. Chandler has courteously furnished ephemerides based upon the best available material, and has devoted much time to correcting the elements and computing the positions corresponding to the times at which certain photographs were taken, as is more fully explained in the *Astronomical Journal*, No. 452.

In making this search the following method of procedure has been adopted. Mr. Chandler, by means of the elements published in the *Astronomical Journal*, No. 451, computed ephemerides for the oppositions of 1894 and 1896. It appeared that the observations then available were insufficient to determine the position in 1894. An error of $1''$ in the mean daily motion in the orbit would change the right ascension of the object in 1894 by about half an hour. Moreover, the value of the daily motion differed by several seconds not only in the early ephemerides of this planet, but in those dependent on a large number of visual observations. Although plates were examined by Mrs. Fleming, covering a region of about 1300 square degrees, the planet was not found. Plates taken in 1896 were next examined, as it was thought that the smaller errors of the ephemeris would compensate for the extreme faintness of the planet. This examination proved to be especially laborious and fatiguing to the eyes. It was feared that the object might be too faint to appear upon the plates and accordingly the faintest objects were carefully scrutinized.

Each plate was examined by superposing it upon another plate of the same region taken with the same instrument. Two adjacent images then appeared of each star, while the planet, if present, would appear only upon the upper plate. Numerous suspicious objects were thus found including several images of the planets Flora (8) and Nysa (44), and two new variable stars, whose approximate positions for 1900 are in R. A. $8^h 33^m.9$, Dec. $+50^\circ 29'$, and R. A. $18^h 38^m.7$, Dec. $-38^\circ 52'$, were discovered. The star $+29^\circ 55'$ fails to appear on ten plates which show other faint Durchmusterung stars, and two stars at R. A. $9^h 11^m.4$, Dec. $-10^\circ 43'$ and R. A. $9^h 11^m.5$, Dec. $-10^\circ 16'$ appear upon the Durchmusterung charts and upon the photographic plates, but are not given in the Durchmusterung catalogue.

At last a faint image was found on a plate taken on June 5, 1896, and confirmed by other plates taken on June 4 and June 5. A plate taken on April 6 covered the region of the planet which was readily found by means of its computed position. Mr. Chandler, from positions of these images, was enabled to furnish a corrected ephemeris for 1894, by means of which the planet was readily detected on several plates. The positions so far found are given below. The successive columns give the number of the plate, the date, the Greenwich Mean Time of the middle of the exposure, the length of exposure in minutes, the approximate right ascension and declination for 1875, and the number of comparison stars used in the determination of the position. The instrument used is indicated by the letter in the first column, A denoting the 24-inch Bruce telescope which was then in Cambridge, B the 8-inch Bache telescope in Arequipa, and I the 8-inch Draper telescope in Cambridge. The method of measurement is that described in the Harvard Observatory Annals, Vol. XXVI, p. 228.

Plate	Date			G. M. T.			Ex.	R. A. 1875			Dec. 1875.			Comp.
	<i>g</i>	<i>m</i>	<i>d</i>	<i>h</i>	<i>m</i>	<i>m</i>		<i>h</i>	<i>m</i>	<i>s</i>	<i>°</i>	<i>'</i>	<i>"</i>	
I 10215	1893	12	19	18	21	14	7	45	57.0		+54	38	41	5
"	"	"	"	"	"	"	7	45	57.5		+54	38	37	5
I 10321	1893	12	27	17	32	10	7	44	43.2		+50	54	45	6
"	"	"	"	"	"	"	7	44	42.8		+50	54	43	6
I 10353	1894	1	1	17	09	59	7	41	34.5		+47	34	±	7
A 246	1894	2	16	14	49	12	7	29	58.3		— 0	21	45	11
"	"	"	"	"	"	"	7	29	58.1		— 0	21	41	11
B 10909	1894	4	16	14	13	10	9	17	0	±	—13	34	15±	7
B 10951	1894	4	18	14	29	10	9	21	48	±	—13	39	1±	7
B 15531	1896	4	6	20	52	60	18	37	0.3		—38	32	51	6
"	"	"	"	"	"	"	18	37	0.5		—38	32	48	6
B 16108	1896	6	4	16	40	70	18	30	5.3		—40	2	46	9
B 16157	1896	6	5	19	54	10	18	27	51.0		—39	58	17	9
B 16165	1896	6	5	22	04	11	18	27	39.1		—39	57	53	9
"	"	"	"	"	"	"	18	27	39.7		—39	58	8	9

I 10321. Image 4° from centre of plate and therefore distorted, but shows direction of motion.

I 10353. Spectrum plate showing that the spectrum of this object, like that of the other planets and of the Sun, is of the second type.

A 246. Image much distorted and elongated.

B 16108. Image much elongated owing to rapid motion.

B 16157. Image very faint, near edge of plate and therefore much distorted, but shows motion by comparison with B 16165.

The following ephemeris and elements have been computed by Mr. Chandler, by combining the observations of 1898 with those derived from the photographs taken December 19 and 27, 1893, February 16, 1894, April 6, 1896, and June 4 and 5, 1896.

EPHEMERIS FOR GREENWICH MIDNIGHT AND EQUINOX OF 1894.0.

Date.	R. A. 1894.0			Dec. 1894.0	v	$\log r$	$\log \Delta$	Magn.
	h	m	s					
1893 Oct. 27.5	5	56	22	+53° 18'.6	-71° 28'.3	0.1120	9.6713	9.86
31.5	6	8	15	54 15.0				
Nov. 4.5	6	20	3	55 4.8	-65 49.4	.1038	.6254	9.59
8.5	6	31	39	55 49.6				
12.5	6	43	0	56 28.4	-59 57.6	.0958	.5778	9.31
16.5	6	53	56	57 0.4				
20.5	7	4	18	57 25.1	-53 52.8	.0881	.5285	9.02
24.5	7	13	59	57 41.3				
28.5	7	22	48	57 47.9	-47 35.4	.0809	.4772	8.73
Dec. 2.5	7	30	29	57 43.8				
6.5	7	36	54	57 27.4	-41 5.7	.0743	.4240	8.43
10.5	7	41	52	56 56.6				
14.5	7	45	19	56 8.8	-34 24.6	.0684	.3692	8.13
18.5	7	47	15	55 1.5				
22.5	7	47	41	53 31.0	-27 33.4	.0634	.3141	7.83
26.5	7	46	44	51 34.2				
30.5	7	44	37	49 7.4	-20 33.5	.0594	.2615	7.55
1894 Jan. 3.5	7	41	34	46 7.8				
7.5	7	37	59	42 34.5	-13 26.9	.0565	.2170	7.31
11.5	7	34	15	38 28.9				
15.5	7	30	45	33 55.4	- 6 15.8	.0548	.1890	7.16
19.5	7	27	46	29 1.3				
23.5	7	25	30	23 58.6	+ 0 57.5	.0543	.1850	7.14
27.5	7	24	6	19 0.1				
31.5	7	23	34	14 15.9	+ 8 10.5	.0552	.2065	7.25
Feb. 4.5	7	24	0	9 55.0				
8.5	7	25	20	6 1.3	+15 20.7	.0572	.2475	7.47
12.5	7	27	37	+ 2 37.3				
16.5	7	30	46	- 0 18.0	+22 25.7	.0604	.2994	7.74
20.5	7	34	41	2 46.8				
24.5	7	39	17	4 51.6	+29 23.5	.0647	.3551	8.04
28.5	7	44	31	6 35.4				
Mar. 4.5	7	50	20	8 1.0	+36 12.1	.0699	.4111	8.35
8.5	7	56	41	9 16.7				
12.5	8	3	32	10 8.5	+42 50.3	.0760	.4654	8.65
16.5	8	10	48	10 55.3				
20.5	8	18	29	11 33.2	+49 16.8	.0828	.5175	8.94
24.5	8	26	30	12 4.0				
28.5	8	34	50	12 29.1	+55 30.9	.0901	.5672	9.23
Apr. 1.5	8	43	25	12 49.3				
5.5	8	52	15	13 5.8	+61 32.2	.0979	.6147	9.50
9.5	9	1	18	13 19.6				
13.5	9	10	34	13 31.3	+67 20.6	.1059	.6604	9.77
17.5	9	19	59	13 41.8				
21.5	9	29	33	-13 51.7	+72 56.1	0.1142	9.7043	10.03

The brightness for 1898, Aug. 24.5 is taken as 11.5 ($\log r = 0.2396$, $\log \Delta = 9.8722$).

ELEMENTS.

Epoch 1898, Aug. 31.5. Gr. M. T.

 $M = 221^{\circ} 35' 45''.6$ $\omega = 177^{\circ} 37' 56''.0$ $\Omega = 303^{\circ} 31' 57''.1$ $i = 10^{\circ} 50' 11''.8$ $\phi = 12^{\circ} 52' 9''.8$ $\mu = 2015''.2326$ $\log a = 0.1637876$ Period = $643^d.10$

A comparison of the observed positions with those obtained by computation is given below. The successive columns contain the date, the Greenwich Mean Time, the apparent right ascension and declination, and the corrections to the ephemerides published in the *Astronomical Journal*, and that given above. The approximate value of the true anomaly is given in the last column.

Date.			G. M. T.			Apparent R. A.			Apparent Dec.			O—C		O—C'		v
												R. A.	Dec.	R. A.	Dec.	
<i>y</i>	<i>m</i>	<i>d</i>	<i>h</i>	<i>m</i>	<i>s</i>	<i>h</i>	<i>m</i>	<i>s</i>	$^{\circ}$	$'$	$''$	<i>m</i>	<i>s</i>	$'$	$''$	$^{\circ}$
1893	12	19	18	21	7 47 29.4	+54	35	50	. . .	. . .	. . .	. . .	. . .	+3.5	0.0	— 30
	12	27	17	32	7 46 11.3	+50	51	57	. . .	. . .	. . .	. . .	. . .	—0.7	—0.3	— 23
1894	1	1	17	09	7 42 59.8	+47	31	$\pm$	. . .	. . .	. . .	. . .	. . .	—1.9	—1.9	— 19
	2	16	14	49	7 30 57.8	— 0	24	9	. . .	. . .	. . .	. . .	. . .	+5.1	—1.0	+ 22
	4	16	14	13	9 17 54.0	—13	39	16	. . .	. . .	. . .	. . .	. . .	+7.6	+0.2	+ 69
	4	18	14	29	9 22 42.6	—13	42	2	. . .	. . .	. . .	. . .	. . .	+7.4	+0.4	+ 71
1896	4	6	20	52	18 38 30.1	—38	31	42	—0	36.0	—4.8	+3.0	+1.3	+1.3	+1.3	+115
	6	4	16	40	18 31 37.4	—40	01	52	—1	16.7	—5.9	+0.9	+1.5	+1.5	+1.5	+142
	6	5	19	54	18 29 23.1	—39	57	28	—1	16.4	—5.6	+1.2	+1.8	+1.8	+1.8	+142
	6	5	22	04	18 29 11.5	—39	57	11	—1	16.7	—5.8	+0.9	+1.7	+1.7	+1.7	+142

The residuals O—C' show that the object on each plate was surely the planet. They by no means represent the accuracy to be expected, either in computation when the perturbations of the Earth are included, or in measurement when time permits the use of more precise methods. Images have since been found on plates taken November 26 and December 23, 1893, and January 19, January 25, January 30 and February 5, 1894.

EDWARD C. PICKERING.

December 26, 1898.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 37.

21

ADDITIONAL OBSERVATIONS OF EROS. (433).

The method of search for Eros, (433), described in Circular No. 36, has been continued. The ephemeris has been extended by Mr. Chandler, as required, and images of the planet have been found by the writer on thirteen plates. From these images the following approximate positions have been determined in addition to those given in Circular No. 36. The successive columns give the number of the plate, the date, the Greenwich Mean Time of the middle of the exposure, the length of the exposure in minutes, and the approximate right ascension and declination for 1875. These positions are, in general, derived from adjacent Durchmusterung stars. Preparations are now being made for precise determinations of the positions of the planet on these plates, and on those described in Circular No. 36. The last two columns give the anomaly and the computed photographic magnitude, assuming the magnitude at distance unity, 12.0, as derived from the measures given in Circular No. 34. The correction for phase is necessarily omitted, and may exceed a magnitude, as the phase angle may amount to 60°. The last three plates were taken at Arequipa, all of the others at Cambridge.

Plate	Date,			G. M. T.		Ex.	R. A. 1875		Dec. 1875.		<i>v.</i>	Magn.
	<i>y</i>	<i>m</i>	<i>d</i>	<i>h</i>	<i>m</i>		<i>h</i>	<i>m</i>	<i>°</i>	<i>'</i>		
I 9801	1893	10	28	21	55	14	5	58.8	+53	40	— 71	10.9
I 9832	1893	10	30	20	18	10	6	4.5	+54	6	— 69	10.8
I 9862	1893	10	31	21	21	15	6	7.6	+54	20	— 69	10.8
I 10095	1893	11	26	20	26	17	7	17.5	+57	50	— 49	9.9
I 10280	1893	12	23	19	49	13	7	45.7	+52	58	— 26	8.8
I 10407	1894	1	8	18	8	65	7	35.5	+41	23	— 12	8.4
I 10469	1894	1	19	16	57	10	7	26.5	+28	46	— 3	8.2
I 10559	1894	1	25	16	16	13	7	23.6	+21	15	+ 3	8.2
I 10604	1894	1	30	13	40	60	7	22.5	+15	20	+ 7	8.3
A 222	1894	2	5	15	26	60	7	23.3	+ 8	46	+ 12	8.4
B 11174	1894	5	19	14	16	10	10	38.0	—14	57	+ 92	11.9
B 16518	1896	6	29	19	17	15	17	37.8	—36	22	+152	12.5
A 1876	1896	6	30	13	46	60	17	36.4	—36	12	+152	12.5

I 9801. This photograph is important since with that taken on May 19, 1894, the anomaly through which the planet was observed in 1893-1894 becomes 162° . The observations contained in Circular No. 36 extended over an angle of 101° .

I 10280. Plate dark, and difficult to measure.

I 10407. Faint spectrum on edge of plate.

I 10469. This plate was fogged and was so dark that it was marked useless. Its density was about that of a shade glass used in viewing the Sun. By making a double contact print from it a photograph is obtained on which accurate measurements of the planet are possible.

I 10604. Spectrum. Superposed on spectrum of $+15^\circ$ 1581, Magn. 9.5.

A 222. Well marked trail $160''$ long, showing irregularities in running of driving clock of telescope.

B 11174. See I 9801.

A 1876. Well marked trail. At about $13^h 15^m$ the planet would have coincided very nearly with -36° 11846. The orbit of the planet could be well determined from the observations in 1896 alone, using for the first place the position of April 6, for the second the three positions on June 4 and June 5, given in Circular No. 36, and for the third, this photograph with that taken on June 29.

Some important conclusions may be derived from this investigation. All the photographs on which the planet has been found were taken with doublets. If they had been taken with lenses of the usual form with a field 2° in diameter all of the images would have fallen outside of the plates. In view of the difficulties found in photographing this object with an ordinary lens at Greenwich and Oxford (Observatory XXI., 429) it is doubtful whether we should have obtained many images of it here with such a lens, even if it had been in regions photographed. The number of plates on which the planet appears probably fairly represents the number we have of all other similar objects whether already discovered or not. This planet is bright during only a small portion of time. During the last eleven years it has been brighter than the ninth magnitude, photographically, for only two months, or about a seventieth part of the entire time. There may be other similar objects, even brighter, as yet undiscovered. Nova Aurigae was as bright as the fifth magnitude for six weeks before it was discovered. Had Eros attained the sixth magnitude instead of the eighth it should have appeared on plates taken with the transit photometer. In this case, we should have had an image of it on every clear night on which it culminated after dark. Fairly good positions could have been obtained from

these images since the focal length of the telescope is about two feet, and the exposures are so short that the images are always circular. We have now a similar instrument in Arequipa so that in general two images should be obtained every night.

EDWARD C. PICKERING.

January 16, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 38.

NEW NEBULAE AND NEBULOUS STARS.

Much care and skill are required to obtain the best results with the Bruce photographic telescope. Dr. De Lisle Stewart, who has had charge of this instrument for the last year, has succeeded in obtaining nearly circular images even when the exposures extended over several hours. He has recently found an interesting group of nebulae, hitherto unknown, within the limits of right ascension, $3^h 10^m$ to $3^h 50^m$ (1900), and declination. $-49^\circ 50'$ to $-53^\circ 40'$ (1900). A comparison of two plates, A 3339, and A 3346, taken on October 14, and October 20, 1898, respectively, with exposures of four hours each, shows the presence of the objects given in the following table. The current number assigned to each object is given in the first column, the approximate right ascension and declination for 1900, in the second and third, and a

No.	R.A. 1900	Dec. 1900.	Description.	No.	R.A. 1900	Dec. 1900.	Description.
	<i>h</i> <i>m</i>	<i>°</i> <i>'</i>			<i>h</i> <i>m</i>	<i>°</i> <i>'</i>	
1	3 10.0	-50 58	2 faint elong. neb.	24	3 26.5	-52 59	Stellar.
2	13.7	51 1	Elong. n to s, small.	25	26.6	-52 58	Stellar.
3	16.0	-49 57	Spiral?	26	27.6	-50 40	Stellar.
4	16.7	-51 3	Elong. n to s.	27	27.7	-50 39	Spiral?
5	17.2	-52 33	Double, elong. sp to nf.	28	27.7	-50 37	Star prec.
6	19.4	-53 33	Elong. n to s.	29	28.1	-50 46	Elong. np to sf.
7	21.4	-53 4	Stellar.	30	28.3	-53 29	Elong. sp to nf.
8	21.7	-51 5	Stellar.	31	28.6	-52 15	Fine small spiral.
9	21.7	-51 3	Stellar.	32	29.4	-52 47	Elong. sp to nf.
10	21.8	-50 55	Stellar.	33	29.9	-51 47	Stellar.
11	22.1	-52 3	Elong. stellar.	34	30.2	-50 45	Elong. np to sf.
12	22.3	-51 37	Elong. np to sf. stellar.	35	30.9	-53 30	Elong. p to f.
13	22.3	-52 3	Elong. stellar.	36	31.2	-51 39	Stellar.
14	22.3	-52 5	Very faint.	37	31.8	-50 58	Stellar.
15	22.5	-51 37	Elong. np to sf.	38	33.2	-52 58	Elong. p to f.
16	22.9	-51 41	Elong. n to s.	39	33.6	-52 18	Elong.
17	22.9	-53 8	Ellip. elong. sp to nf.	40	33.6	-52 19	Elong.
18	23.1	-50 22	Stellar, elong. spiral?	41	33.7	-49 54	Elong. np to sf.
19	23.5	-51 40	Stellar, elong. np to sf.	42	34.1	-50 29	Elong. n to s.
20	24.4	-53 22	Perhaps double star.	43	39.1	-51 17	Stellar.
21	24.8	-51 25	Elong. p to f.	44	41.9	-51 51	Stellar, elong. sp to nf.
22	24.8	-52 29	Neb. star.	45	42.3	-51 19	Stellar.
23	25.2	-53 1	Stellar, elong. n to s.	46	43.0	-51 58	Elong. n to s.

brief description of the object in the fourth column. The letters n, s, p, and f, in the fourth column are used to indicate, north, south, preceding, and following, respectively.

Only two nebulae are given, in this region, in Dreyer's New General Catalogue. N. G. C. 1311 is identical with No. 5, and N. G. C. 1356 is identical with No. 27.

It will be noticed that four of these nebulae appear to be spiral. No. 3 is described as "bright elongated centre, faint nebulous wisps in ellipses or spiral." No. 18 "stellar nucleus with elliptical nebulosity sp." No. 27 "Faint Nebulous star surrounded by nebulosity. One wisp has spiral tendency. Two nebulous stars sp. and sf, very close to main nebulosity." No. 31, "Very fine small spiral nebula with two branches."

A bright meteor trail appears on Plate A 3346.

EDWARD C. PICKERING.

January 31, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 39.

A NEW FORM OF PHOTOGRAPHIC TELESCOPE.

A great number of very large telescopes of nearly the same form have been given to observatories during the last few years. Although such instruments are indispensable, in a limited number of investigations, yet when the latter are divided among so many telescopes the results obtained by each are often disappointing to the donors. These instruments have been erected, with two or three exceptions, in places selected from local or political motives, and without regard to meteorological or astronomical conditions. For this reason, the great observatories of the world are near large cities or universities where the very conditions that have rendered the countries great have rendered them unfit for the most delicate astronomical research. Nine tenths of these instruments are in the temperate zone in Europe and the United States, while the southern hemisphere has been entirely neglected and many of the most interesting parts of the southern sky have not yet been examined by a modern telescope of the largest size.

This duplication of expensive instruments in unsuitable localities is rendered still more objectionable by another condition. All the telescopes are similar in form, their focal length being from 15 to 18 times the aperture, and therefore, all are best adapted to the same kind of work. In view of these numerous precedents it was a bold step to deviate from it. But this step was taken, and taken by a woman. Miss Catherine W. Bruce of New York, who gave \$50,000 to the Harvard College Observatory to construct a telescope of 24 inches aperture, in which the focal length should be only six times the aperture. Fortunately, this experiment succeeded, and the Bruce Photographic Telescope is mounted in Arequipa, Peru, in a climate unsurpassed, so far as is now known, for astronomical work. Its immediate results are charts, each covering a large part of the sky and showing such faint stars that 400,000 appear

upon a single plate. By its aid, many new stars of the peculiar fifth type have been found in the Large Magellanic Cloud, showing an additional connection of this object with the Milky Way. A group of forty nebulae, hitherto unknown, has been found in another part of the sky. The most important work of the Bruce telescope, however, is that every year it sends hundreds of photographs to the great storehouse at Cambridge. Besides the immediate discoveries made from these plates, they doubtless carry with them many secrets as yet unrevealed, and many images of objects of the greatest interest yet to be discovered. A striking example of this kind is found in the recent discovery of the planet Eros, which, next to the Moon, is sometimes our nearest neighbor in the heavens. Calculation showed that this planet must have been near the Earth, and therefore bright, in 1894. An examination showed that this object, although not discovered until 1898, had not escaped the Harvard telescopes. Two images of it were found upon the Bruce plates, fifteen upon the Draper plates and three upon the Bache plates. It can thus be followed through nearly half a revolution. Six images were also obtained in 1896, when it was more distant and much fainter.

These examples show the advantages of trying new forms of telescopes instead of duplicating those now existing. The Bruce telescope is well adapted to investigations in which the focal length is small. It will therefore be interesting to try the effect of a great focal length. It is proposed to build a telescope with an aperture of 12 to 14 inches, and a focal length of 135 or 162 feet. This telescope would probably be placed horizontally and the star reflected into it by means of a mirror, the motion of the Earth would be counteracted by moving the photographic plate by clock work. It would thus become a large horizontal photoheliograph. This method of mounting a telescope for use on the stars was advocated by the writer in 1881, and has been used here since then with successive telescopes of 2, 4, and 12 inches aperture. The instrument here proposed would be adapted to investigations for which a great focal length would be needed, as the latter would be more than a hundred times the aperture. Several such investigations may be suggested, any one of which, if successful, would amply justify the construction of such an instrument.

1. The Sun. The best instrument now in use for photographing the Sun, the horizontal photoheliograph, is a small instrument of this form. It is possible that, under favorable atmospheric conditions, finer details on the Sun's surface could be obtained with a large instrument than have yet been photographed. It would be equally useful in photographing the protuberances. Preparations must soon be made

for observing the Solar Eclipse of May 28, 1900. This instrument might be useful in photographing the spectrum of the reversing layer, and in showing the details of the inner corona.

2. The Moon. The images of the Moon obtained with such a telescope would be more than a foot in diameter and even if printed without enlargement would probably surpass the best photographs yet taken. The use of a telescope of this form for photographing the Moon was advocated by Professor W. H. Pickering in 1894 (*Harvard Observ. Ann.* XXXII p. 110). It is possible that good results could also be obtained with Jupiter, Saturn, and perhaps Mars.

3. Eros. This planet approaches the Earth so closely that its parallax sometimes amounts to a minute of arc. The next approach, in 1900, will be more favorable than any other until 1927. Careful preparations should, therefore, be made for observing Eros when east and west of the meridian, since the distance of the Sun can probably be determined with more accuracy in this way than by any method of observation yet attempted. As the distance of the Sun is the unit to which all astronomical distances are referred, the importance of its accurate determination cannot be overstated. It is one of the great problems of astronomy which though supposed in the eighteenth century to have been solved, must probably be left to the twentieth century for satisfactory solution. To determine the parallax from the Transit of Venus in 1874, the principal nations of the world sent expeditions to the most remote regions. In all, about eighty stations were occupied at an expense of more than a million of dollars.

4. The Fixed Stars. It is expected that the positions of adjacent stars could be determined with this instrument with an accuracy approaching that of the heliometer. If so, it would have an important and permanent field of work in charting the coarser clusters, the double stars, and determining stellar parallax. Also in locating the major planets, and the relative positions of the satellites of Jupiter and Saturn with an accuracy as yet unattained.

The very moderate expenditure of \$5,000 to \$10,000 would permit this experiment to be tried here, since we already have a portion of the apparatus required. If successful, the name of the donor would always be honorably associated with a new departure in one of the most important branches of astronomy.

EDWARD C. PICKERING.

February 11, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 40.

PHOTOGRAPHING METEORS.

Various plans have been considered by which all the meteors visible in a large part of the sky at Cambridge can be photographed. Such a plan does not seem impracticable or premature, in view of the large number of meteors photographed during the shower of last November. The simplest device consists in pointing a camera, having a wide angle lens, to the zenith. Two meteor trails were obtained in this way on November 14, 1898. Morrison wide angle lens of 8 inches focal length was used, and an 8×10 plate. Since then, plates have been exposed on several clear nights, and on the second night, January 7, 1899, a meteor was photographed. About one third of all the meteors having long paths, and visible at a single station, pass within 30° of the zenith, and all of these, if bright, could thus be photographed. Our knowledge of very bright meteors is extremely limited. They are so few in number that we cannot determine their radiant points in the usual way, and unless they happen to be observed carefully from more than one station, little information is obtained regarding them. The radiant point can be determined by observations of a single meteor from two stations, as well as from the intersection of two meteor trails as seen from one station. Two such cameras have been constructed and will be in operation shortly at Blue Hill and at Cambridge. They are provided with caps actuated by alarm clocks, so that the exposure is stopped automatically shortly before dawn. The operator need only expose a plate in the evening, after dark, and remove and develop it at his convenience the next day. If now, two photographs are obtained of the same meteor, much information will be furnished regarding it. Bright meteor trails often show points of increased brightness due to small explosions. Superposing the two photographs, the height of the meteor at the instant of explosion is given by a simple proportion. As the distance of the meteor on the two photographs is to

the focal length of the lenses, so is the distance apart of the two stations, to the required altitude. A similar computation may be made from the distance apart and azimuths, of the trails themselves, if no distinctive points appear on them. The positions of the trails in space can be determined if the plates are levelled, or from the trails of the stars which also appear on the plates. The intersection of the two trails gives the declination of the radiant point of the meteor, but its right ascension is indeterminate unless the time at which the meteor appeared is noted. This difficulty might be remedied by mounting the camera equatorially, and it is possible that this plan may be adopted later.

The spectra of bright meteors could be obtained by placing a prism in front of the lens of the camera. In this case, the value of the result would be greatly increased by giving a motion to the photographic plate. For instance, if a vibratory motion is given to the latter, like that of a pendulum, the image of the meteor as it traversed the plate would have a relative motion which would be continually varying. At one point it might become small, so that we should be virtually following the meteor by clockwork, as in the case of a star, and at this instant its spectrum would be photographed even if not very bright. If the period of vibration is a second, or less, two or more images of each meteor would appear at intervals equal to the time of vibration. This would give the angular motion of the meteor, and, if its distance is known, its absolute velocity.

By the expenditure of three plates a night it seems possible to determine the altitude, radiant point, velocity, and spectrum of one third of all the bright meteors visible in a given locality. It is probable that several meteors bright enough to be photographed in this way appear every month.

EDWARD C. PICKERING.

February 20, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 41.

THE VARIABLE STARS U VULPECULAE AND ST CYGNI.

The variability of the stars $+20^{\circ}4200$ and $+28^{\circ}3460$ has been announced, and the designations U Vulpeculae and ST Cygni assigned to them by Professor Müller and Dr. Kempf of the Potsdam Observatory (*Astron. Nach.*, **146**, 37). Measures of these stars have accordingly been made by Professor O. C. Wendell, with the photometer with achromatic prisms attached to the 15 inch Equatorial of this Observatory. The star $+20^{\circ}4200$ was compared with the star $+20^{\circ}4204$, which is about $12'.6$ distant. The results of these measures are shown by the heavy dots in Figure 1, ordinates representing magnitudes, and abscissas, phases, or intervals in days since the last computed maximum. The measures made at Potsdam are represented by the light dots connected by lines, and the dotted line shows the light curve given in the article mentioned above. The results for $+28^{\circ}3460$, which was compared with $+28^{\circ}3467$, distant $15'.0$, are similarly shown in Figure 2. It will be seen that a smooth curve

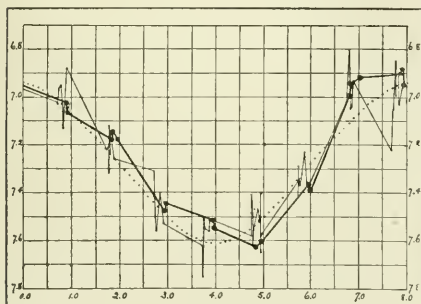


FIG. 1.

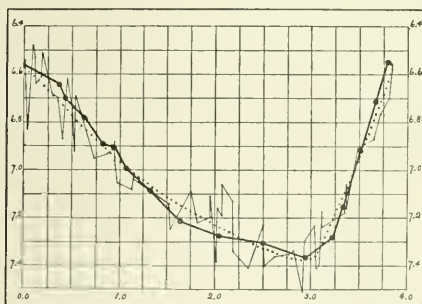


FIG. 2.

can be drawn, which would not differ on the average by more than one or two hundredths of a magnitude from the points observed here. The greater accordance of the Harvard measures as compared with those made at Potsdam, is partly due to the greater number of settings made each night, and partly to the smaller angular distance between the stars compared. At Cambridge, adjacent stars are compared directly, while at Potsdam, each star is compared with the standard stars by means of an artificial star. In drawing the light curve of $+20^{\circ}4200$, too great weight seems to have been given to the Potsdam observation for which the phase is $7^d.7$,

magnitude 7.22. Rejecting this, the other Potsdam observations agree closely with those made at Cambridge. To reduce the results to the same scale, the Cambridge magnitudes have been changed by $+0.16$ and $+0.32$, and the phases by $+0^{\circ}.8$ and $-0^{\circ}.2$, in Figures 1 and 2 respectively. This indicates that the period of $+20^{\circ} 4200$ is $7^{\text{d}}.98$, instead of $8^{\text{d}}.00$.

S ANTILAE.

The accuracy attainable with the photometer described above is illustrated by the following observations of the variable star, S Antliae. This star has a period of $7^{\text{h}} 46^{\text{m}}.8$, which is the shortest known, except in the case of variables in clusters. In Circulars Nos. 23 and 25, it was shown that the period of U Pegasi, which was at one time supposed to be shorter than that of any other variable, should really be doubled. The alternate minima were bright and faint, the difference in magnitude amounted to 0.15 and was determined with a probable error but little exceeding one hundredth of a magnitude. It, therefore, appeared important to see if S Antliae belonged to the same class of variables, and if its period should be doubled. A series of measurements was accordingly made by Professor Wendell on different nights near the times of minima, care being taken that some of the minima should correspond to an odd, and others to an even number of periods of variation, E . The comparison star was $-28^{\circ} 7347$, distant, $21'.8$. A light curve was then formed from these measures, and residuals taken from it. On two nights E was odd, 11229 and 11349, and the means of the corresponding residuals were $+0.011$ and 0.000 ; on three nights E was even, 11306, 11340, and 11346, and the mean residuals were $+0.004$, -0.007 , and $+0.008$. The assumed value of the difference in magnitude of S Antliae when at minimum and $-28^{\circ} 7347$, was -1.676 . Accordingly, the mean difference in magnitude at minimum when E was odd, was -1.670 , and when E was even, -1.674 . It seems impossible that thousandths of a magnitude should have any real value, but if neglected, the accuracy of these observations would not be properly indicated. An error of two or three hundredths of a magnitude could not have failed to be detected. The variable star S Antliae, therefore, does not have a light curve resembling that of β Lyrae and U Pegasi, and the period of variation should not be doubled.

EDWARD C. PICKERING.

February 21, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 42.

A NEW STAR IN SAGITTARIUS.

A new star appeared in the constellation Sagittarius early in the year 1898, or possibly in the latter part of the year 1897. It was found from the peculiarities of its spectrum, by Mrs. Fleming, during the examination of the Draper Memorial photographs. The approximate position for 1900, derived from a photographic chart, using the Durchmusterung positions of adjacent stars, is R.A. = $18^h 56^m.2$, Dec. = $-13^\circ 18'$. It was too faint to be photographed on eighty-seven plates, from September 5, 1888, to October 23, 1897, including three plates in 1888, one in 1889, three in 1890, eleven in 1891, three in 1892, twelve in 1893, ten in 1894, twenty-one in 1895, eight in 1896, and fifteen in 1897. On the last of these plates, A 2845, taken at Arequipa with the Bruce telescope, stars of the fifteenth magnitude are shown, but the Nova is invisible. The Nova appears on eight photographs taken in March and April, 1898. In the description of them given below, the designation of the plate is followed by the date and the exposure. The letter B indicates that the photograph was taken at Arequipa with the 8-inch Bache telescope, and I, that it was taken at Cambridge with the 8-inch Draper telescope. Both of these instruments are doublets. The magnitudes are estimated by comparison with adjacent stars, and are approximate only, especially since the image was near the centre of the plate only on B 21251, B 21258, and B 21319.

I 20428. March 8, 1898. Ex. 13^m . Magn. 4.7. Estimated 0.1 fainter than $-16^\circ 5283$, photometric magn. 4.6.

I 20500. March 14, 1898. Ex. 13^m . Magn. 5.0. Estimated 0.5 fainter than $-16^\circ 5283$, and 0.4 brighter than $-14^\circ 5476$, photometric magn. 5.6.

I 20612. April 3, 1898. Ex. 16^m . Magn. 8.2.

B 21251. April 19, 1898. Ex. 60^m . Magn. 8.2. An excellent photograph of the spectrum, 3 mm. in length, and showing the lines H β , H γ , H δ , H ϵ , H ζ , H η , and probably H θ , bright. A broad band, wave length 4643, is also bright, and narrow bright lines are seen at about 4029, 4179, 4238, 4276, 4459, and 4536. These lines appear to be identical with the corresponding lines found in the spectrum of Nova

Aurigae. A well marked dark line appears at 4060. It will be noticed that in this star, as in Nova Persei, Nova Aurigae, Nova Normae, and Nova Carinae, the line $H\epsilon$ is bright, while in variable stars of long period this line is always dark, being probably obscured by the broad calcium line II. This alone may serve to distinguish between a Nova and a variable. The accompanying dark lines on the edge of shorter wave length of the bright lines in Nova Aurigae, Nova Normae, and Nova Carinae are not visible. The line K, also, is not shown.

I 20738. April 21, 1898. Ex. 9^m . Magn. 8.6.

B 21258. April 21, 1898. Ex. 62^m . Magn. 8.2. The spectrum closely resembles that on B 21251 taken two days earlier, but shows certain marked differences. The broad dark line at 4060 has disappeared, and a narrow bright line appears at 5005, doubtless identical with the principal nebular line, 5007. The hydrogen lines appear to be somewhat narrower and more intense than in the earlier photograph, although the lines in the adjacent stars are nearly the same in both.

B 21290. April 26, 1898. Ex. 10^m . Magn. 8.2.

B 21319. April 29, 1898. Ex. 10^m . Magn. 8.4.

The region of the Nova is included on two, and perhaps three plates taken at Arequipa on October 7 and 8, 1898, but not yet received in Cambridge. They will later furnish important information regarding the rate of diminution of the light. On March 9, 1899, the morning after the discovery of the Nova, a faint image of it was obtained through passing clouds, which showed that its photographic image was about half a magnitude fainter than that of $-13^{\circ}5193$, magn. 9.5. On the morning of March 13, 1899, the Nova was examined visually by Professor O. C. Wendell. He found, first, that its position for 1900 is R.A. = $18^h 56^m 12^s.2$, Dec. = $-13^{\circ} 18' 16''$. Secondly, that it was 1.52 magn. fainter than $-13^{\circ} 5200$, and therefore 11.37 on the photometric scale. Thirdly, that its light was nearly monochromatic with a faint continuous spectrum. This Nova, therefore, like several that have preceded it, appears to have changed into a gaseous nebula. This is also indicated by the faint bright line at 5005, which, as stated above, appeared in the photograph of its spectrum taken April 21, 1898.

During the last four centuries, fifteen stars have appeared which are commonly regarded as Novae. These stars are, in general, near the central line of the Milky Way. Their average galactic latitude is $11^{\circ}.2$, while if uniformly distributed in the sky it would be 30° . The region whose galactic latitude is less than 30° has an area

equal to one-half of that of the whole sky. Fourteen of these stars appeared in this region, and only one, Nova Coronae, outside of it. Nova Andromedae and Nova Centauri had spectra without bright lines, and unlike other Novae. Omitting them, the average galactic latitude of the others is $9^{\circ}.0$. The galactic latitude of Nova Coronae is $46^{\circ}.8$, and this seems to be the only known exception to the rule that all Novae having bright lines in their spectra have appeared near the central line of the Milky Way. Omitting this star, the average galactic latitude of the other twelve is $5^{\circ}.8$. The only Novae known to have bright lines in their spectra are those which appeared in Corona, Cygnus, Perseus, Auriga, Norma, Carina, and Sagittarius. Omitting the first of these, the mean galactic latitude is $4^{\circ}.6$. The probability that such a distribution is due to accident, is extremely small.

EDWARD C. PICKERING.

March 14, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 43.

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A NEW SATELLITE OF SATURN.

Nearly all of the astronomical discoveries made by the aid of photography have related to the fixed stars. In the study of the members of the solar system, the results obtained by the eye are generally better than those derived from a photograph. For many years it has been supposed that photography might be used for the discovery of new satellites, and in April, 1888, a careful study of the vicinity of the outer planets was made by Professor William H. Pickering. Photographs were taken with the 13-inch Boyden telescope, with exposures of about one hour, and images were obtained of all the satellites of Saturn then known, except Mimas, whose light is obscured by that of its primary. It was then shown that Saturn probably had no satellite, as yet undiscovered, revolving in an orbit outside of that of Enceladus, unless it was more than a magnitude fainter than Hyperion. (Forty-third Report, p. 8.)

In planning the Bruce Photographic telescope, a search for distant and faint satellites was regarded as an important part of its work, and accordingly, plates for this purpose were taken at Arequipa, by Dr. Stewart. A careful examination of these plates has been made by Professor William H. Pickering, and by superposing two of them, A 3228 and A 3233, taken August 16 and 18, 1898, with exposures of 120^m , a faint object was found which appeared in different positions on the two plates. The same object is shown on two other plates, A 3227 and A 3230, taken August 16 and 17, 1898, with exposures of 60^m and 122^m , respectively. The position is nearly the same on the two plates taken August 16, but on August 17 it followed this position $33''$, and was south $19''$, while on August 18 it followed $72''$, south $43''$. Its motion was direct, and less than that of Saturn, though nearly in the same direction. It cannot, therefore, be an asteroid, but must be either a satellite of Saturn or a more distant outside planet. The proximity of Saturn, renders the first supposition much more probable. On August 17, the position angle from Saturn was 106° , and the distance $1480''$. Assuming that it was at elongation, and that its orbit is circular, its period would be 400 days, or five times that of Iapetus.

It was at first identified with a very faint object found on plates taken in 1897, and the period of seventeen months was derived from them. This supposition has not been confirmed.

Measurements of the positions of the images give additional material for determining the form of the orbit. The method of measurement is that described in the *Annals*, Vol. XXVI, p. 236. The uncorrected positions of the four images referred to the first plate of August 16 as an origin, are for x , $0''.0$, $+1''.2$, $+33''.6$, and $+71''.8$; for y , $0''.0$, $-1''.7$, $-19''.8$, and $-42''.1$; the corresponding Greenwich mean times are $12^h 16^m$, $14^h 18^m$, $12^h 56^m$, and $13^h 12^m$. Correcting for the motion of Saturn, the relative motion with reference to that body is in x , $0''.0$, $-2''.4$, $-10''.7$, and $-22''.0$; in y , $0''.0$, $+0''.1$, $+2''.4$, and $+2''.9$. It appears from this, that the apparent motion is about $10''.4$ a day, at a distance of $1480''$. A computation shows that if the orbit is circular, the period must be either 4200 or 490 days, according as the satellite is near conjunction or elongation. These values may be greatly altered if the orbit is elliptical. Since the interval of time between the first and last photographs on which the satellite appears is only two days, it is impossible to predict its position with accuracy. It is probable that its position angle from Saturn now lies between 280° and 290° , and its distance between $20'$ and $30'$. These uncertainties will probably be greatly diminished from measures of plates of Saturn taken in Arequipa on September 15, 16, and 17, 1898, which for some unexplained reason have not yet been received in Cambridge.

The direction of the motion, which is nearly towards Saturn, shows that the apparent orbit is a very elongated ellipse, and that it lies nearly in the plane of the ecliptic. Professor Asaph Hall has pointed out that this is to be expected in a body so distant from Saturn. The attraction of the latter only slightly exceeds that of the Sun. Hyperion appears as a conspicuous object on all four of the plates, and the new satellite appears about a magnitude and a half fainter on each. The approximate magnitude is therefore about 15.5. As seen from Saturn, it would appear as a faint star of about the sixth magnitude. Assuming that its reflecting power is the same as that of Titan, its diameter would be about two hundred miles. It will, therefore, be noticed that while it is probably the faintest body yet found in the solar system, it is also the largest discovered since the inner satellites of Uranus in 1851. The last discovery of a satellite of Saturn was made in September, 1848, by Professor William C. Bond, then Director of this Observatory, and his son, Professor George P. Bond.

The satellite Hyperion was seen by the son on September 16 and 18, but its true character was first recognized on September 19, when its position was measured by both father and son (See *Annals*, II, p. 12). Soon after, it was discovered independently by Lassell at Liverpool.

Professor William H. Pickering, as the discoverer, suggests that the name Phoebe, a sister of Saturn, be given to the new satellite. Three of the satellites, Tethys, Dione and Rhea have already been named for Saturn's sisters, and two, Hyperion and Iapetus, for his brothers.

EDWARD C. PICKERING.

April 10, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 44.

THE NEW ALGOL VARIABLE IN CYGNUS. $+45^{\circ} 3062$.

An announcement is made in the *Astronomische Nachrichten*, **149**. 271, that the star $+45^{\circ} 3062$, R.A. $= 20^h 2^m.4$, Dec. $= +45^{\circ} 53'$ (1855), magn. 8.6, is a variable star of the Algol type. Mme. L. Ceraski of Moscow found it abnormally faint on a photographic plate taken on May 20, 1898, and M. S. Blajko, after observing it visually for a long time, found it again at minimum on May 7, 1899. An examination was accordingly made of the Draper Memorial photographs to determine the nature of the variation. The region was covered by 195 plates, 170 of which showed the star at its full brightness, including 28 taken in 1890, 18 in 1891, 22 in 1892, 17 in 1893, 13 in 1894, 17 in 1895, 21 in 1896, 17 in 1897, 12 in 1898, and 5 in 1899. Besides these, twenty plates show the star when it was below its normal brightness. From a discussion of these plates it appears that the minima they indicate, as well as the two minima found at Moscow, may be closely represented by the formula J.D. $2,411,343^d.605 + 4^d.57294 E$. The period, therefore, is $4^d 13^h 45^m.2^s$, with an uncertainty which probably does not exceed one or two seconds. The variation in brightness of this star amounts to about three magnitudes, and, therefore, exceeds that of any Algol star hitherto discovered. Like all other Algol stars, its spectrum is of the first type.

The announcement of the discovery of this variable reached this Observatory on June 1. On June 3, the elements and ephemeris had been determined just in time to prepare for the minimum of that night. Accordingly, the star was followed all night by Professor Wendell, assisted by Mr. Leon Campbell, and 272 settings were made with the photometer attached to the 15 inch Equatorial. From these it appears that at $16^h.0$ G. M. T., it was 0.20 magnitudes brighter than the comparison star, $+45^{\circ} 3067$, while at $19^h.9$ G. M. T., when observations were stopped by the dawn, it was 2.25 magnitudes fainter than the same comparison star, although it was still $1^h.5$ before the predicted minimum. Observations by Argelander's method were also made all night by Mr. Wm. M. Reed, with the 6 inch Equatorial. Mean-

while, thirty photographic images were obtained by Mr. H. R. Colson, assisted by Mr. E. R. Cram.

The minima so far observed are given in chronological order in the following table, including, on June 3 and 8, only the photographs taken with the 8 inch Draper telescope. The value of E is given in the first column. The second column gives the designation of the plate, A denoting the 24 inch Bruce telescope, B the 8 inch Bache telescope, and I the 8 inch Draper telescope. B 1719, I 231, I 907, I 1303, I 3719, I 7744, and I 11504 are spectrum plates. The date on which the photograph was taken, the Greenwich Mean Time, the Julian Day omitting the three left hand figures, 241, and the fraction of a day following Greenwich Mean Noon, and the length of exposure, are given in the next four columns. The photographic magnitude is given in the seventh column, the computed time of minimum in the eighth, and the observed minus the computed in the ninth column. The tenth column gives a correction for the magnitude of the star derived from the figures given in the seventh and ninth columns. The sign is indeterminate, and corresponds with the assumption that the period is uniform. The corrected residuals are given in the eleventh column. No correction has been applied for the light equation. The error from this cause is small since the star is not very far from the pole of the ecliptic. The last column gives the error in the observed magnitude assuming the computed magnitude to be correct.

OBSERVED MINIMA.

E.	Plate.	Date.			G. M. T.		J. D.		Ex.	Magn.	Comp.	O-C.	Corr.	O-C.	Err.
		y	m	d	h	m	d								
—176	B 1719	1887	9	23	13	10	0538.549		70	<9.1	0538.768	—,219	.	.	.
0	I 231	1889	12	6	11	28	1343.478		113	9.83	1343.605	—,127	+.132	+.005	—,03
+ 25	I 907	1890	3	30	20	49	1457.867		87	<9.9	1457.928	—,061	.	.	.
42	I 1303	1890	6	16	17	41	1535.737		75	<9.9	1535.668	+.069	.	.	.
52	I 1540	1890	8	1	14	38	1581.610		13	9.17	1581.398	+.212	—,224	—,012	—,06
59	I 1777	1890	9	2	14	48	1613.617		13	9.27	1613.408	+.209	—,203	+.006	+.03
121	I 3719	1891	6	12	18	57	1896.790		60	9.90	1896.931	—,141	+.126	—,015	+.21
244	I 7744	1892	12	26	12	44	2459.531		59	9.89	2459.402	+.129	—,126	+.003	+.05
297	I 9300	1893	8	25	13	53	2701.578		11	9.32	2701.768	—,190	+.191	+.001	.00
351	A 582	1894	4	29	20	10	2948.840		12	9.92	2948.707	+.133	—,125	+.008	+.11
384	I 11504	1894	9	27	13	37	3099.567		70	<10.2	3099.614	—,047	.	.	.
387	I 11585	1894	10	11	13	1	3113.542		11	9.17	3113.333	+.209	—,224	—,015	—,08
471	I 13759	1895	10	30	13	47	3497.574		10	10.21	3497.460	+.114	—,113	+.001	+.06
503	I 14711	1896	3	24	19	30	3643.812		26	11.78	3643.794	+.018	—,031	—,013	—,01
517	I 15182	1896	5	27	16	43	3707.697		12	10.11	3707.815	—,118	+.116	—,002	+.03
522	I 15328	1896	6	19	17	30	3730.729		11	11.68	3730.680	+.049	—,047	+.002	.00

E.	Plate.	Date.	G. M. T.	J. D.	Ex.	Magn.	Comp.	O-C.	Corr.	O-C ¹ .	Err.
		<i>y m d</i>	<i>h m</i>	<i>d</i>	<i>m</i>		<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>	
+543	I 16009	1896 9 23	16 19	3826.680	13	11.88	3826.711	-.031	+.010	-.021	+.09
555	I 16569	1896 11 17	10 39	3881.444	11	9.61	3881.587	-.143	+.149	+.006	-.07
632	I 19445	1897 11 4	13 10	4233.549	11	9.72	4233.703	-.154	+.139	-.015	+.16
675	"	1898 5 20	"	4430.4	"	"	4430.339	+.061	"	"	"
749	I 22770	1899 4 23	20 14	4768.843	23	10.23	4768.737	+.106	-.112	-.005	-.15
752	"	1899 5 7	10 54	4782.446	"	"	4782.456	-.010	"	"	"
758	I 22981	1899 6 3	15 55	4809.663	10	9.22	4809.894	-.231	+.222	-.009	+.08
758	I 22982	1899 6 3	16 57	4809.706	11	9.60	4809.894	-.188	+.151	-.037	+.01
758	I 22986	1899 6 3	19 40	4809.819	12	11.38	4809.894	-.075	+.067	-.008	+.20
758	I 22987	1899 6 3	20 6	4809.837	4	11.54	4809.894	-.057	+.057	.000	.00
758	I 22988	1899 6 3	20 13	4809.842	1	<10.8	4809.894	-.052	"	"	"
759	I 22995	1899 6 8	14 00	4814.583	13	9.95	4814.466	+.117	-.122	-.005	-.17
759	I 22996	1899 6 8	14 14	4814.593	10	9.85	4814.466	+.127	-.129	-.002	-.06
759	I 22997	1899 6 8	14 29	4814.603	15	9.88	4814.466	+.137	-.127	+.010	+.14
759	I 22998	1899 6 8	14 43	4814.613	10	9.58	4814.466	+.147	-.153	-.006	-.06
759	I 22999	1899 6 8	14 53	4814.620	10	9.55	4814.466	+.154	-.156	-.007	-.01
759	I 23000	1899 6 8	15 9	4814.631	19	9.55	4814.466	+.165	-.156	+.009	+.07
759	I 23003	1899 6 8	16 32	4814.689	14	9.22	4814.466	+.223	-.213	+.010	+.06

E 675. This is the date on which the plate was taken, from which Madame Ceraski discovered the variable. The time is not given, but, owing to the northern latitude of Moscow has been assumed to be near midnight. As the brightness is not stated, no correction for magnitude can be applied.

E 752. Found by M. Blajko from visual observations.

E 758. The last plate, I 22988, was taken in strong twilight so that the Pole Star was barely visible. The plate was not fogged, but the star had become too faint to be photographed.

On five plates, taken at 0519.592, 1720.483, 1935.849, 3058.784, and 3859.525, the variable appears to be about two tenths of a magnitude below its maximum brightness, 8.96, but the phase shows that it was not at minimum. On a few plates the variable appears a little brighter than normal, but these small variations are probably due to photographic effects, such as distance from centre of plate, or difference in color, which affects chart images differently from spectra.

The average value of the residuals in the last column is ± 0.07 . It will, therefore be seen that the formula given above serves to compute the magnitudes for the last ten years with such accuracy that they differ from the measured values on the average by less than a tenth of a magnitude. Even these small differences could doubtless be diminished by applying the correction for the light equation, by correcting the light curve since the positive residuals slightly exceed the negative, and by remeasuring the more discordant plates. In each of the five cases in which the star is not seen, indicated by the sign < followed by the magnitude of the faintest star

visible on the plate, computation shows that the variable must have been fainter than this magnitude. An ephemeris for the remainder of the year is given below.

EPHEMERIS OF HELIOCENTRIC MINIMA.

E.	J. D.	Min. 1899.				E.	J. D.	Min. 1899.				E.	J. D.	Min. 1899.			
		m	d	h	m			m	d	h	m			m	d	h	m
758	4809.89352	6	3	21	26	774	4883.06056	8	16	1	28	790	4956.22760	10	28	5	28
759	4814.46646	6	8	11	11	775	4887.63350	8	20	15	12	791	4960.80054	11	1	19	13
760	4819.03940	6	13	0	56	776	4892.20644	8	25	4	57	792	4965.37348	11	6	8	57
761	4823.61234	6	17	14	41	777	4896.77938	8	29	18	42	793	4969.94642	11	10	22	42
762	4828.18528	6	22	4	26	778	4901.35232	9	3	8	27	794	4974.51936	11	15	12	27
763	4832.75822	6	26	18	11	779	4905.92526	9	7	22	12	795	4979.09230	11	20	2	12
764	4837.33116	7	1	7	56	780	4910.49820	9	12	11	58	796	4983.66524	11	24	15	57
765	4841.90410	7	5	21	42	781	4915.07114	9	17	1	42	797	4988.23818	11	29	5	43
766	4846.47704	7	10	11	27	782	4919.64408	9	21	15	27	798	4992.81112	12	3	19	28
767	4851.04998	7	15	1	12	783	4924.21702	9	26	5	12	799	4997.38406	12	8	9	13
768	4855.62292	7	19	14	57	784	4928.78996	9	30	18	57	800	5001.95700	12	12	22	58
769	4860.19586	7	24	4	42	785	4933.36290	10	5	8	43	801	5006.52994	12	17	12	43
770	4864.76880	7	28	18	27	786	4937.93584	10	9	22	28	802	5011.10288	12	22	2	28
771	4869.34174	8	2	8	12	787	4942.50878	10	14	12	13	803	5015.67582	12	26	16	13
772	4873.91468	8	6	21	57	788	4947.08172	10	19	1	58	804	5020.24876	12	31	5	58
773	4878.48762	8	11	11	43	789	4951.65466	10	23	15	43						

It will be noticed that nearly a year would have been saved had the original discovery of the variability of this star been sent here for confirmation from the photographs, or had it been announced publicly. There is so little chance for error in a photograph that such cases are always examined here. Confirmation is not always obtained. A striking instance of this kind is furnished by a photograph, X 7524 taken at Arequipa with the 13 inch Boyden telescope on May 22, 1896 at 14^h 20^m G. M. T. Miss A. J. Cannon found that this plate shows the spectra of A. G. C. 17312, 17497, and 17453, magns. 7.0, 7.2 and 7.5 respectively, but fails to show the spectrum of the brighter star A. G. C. 17270, magn. 6.0. Apparently this is an Algol star observed at one minimum only. On 153 other plates the star appears of its normal brightness. On a photograph, C 7354, taken at Cambridge with the 11 inch Draper telescope on December 18, 1894 at 11^h 8^m G. M. T., the star, + 42° 4182, magn. 9.1 was found by Miss L. D. Wells to be absent, although stars two and a half magnitudes fainter were shown. On plate C 7353 taken twelve minutes earlier, and on 259 other plates, it appears of its normal brightness. An adjacent defect in the film of the first plate is perceptible, and perhaps explains the absence of this star.

EDWARD C. PICKERING.

June 10, 1899.

HARVARD COLLEGE OBSERVATORY:

CIRCULAR NO. 45.

THE NOVEMBER METEORS OF 1899.

The predicted time of maximum of the November Meteors is November 15, 1899, at 18^h Greenwich Mean Time. As a similar shower may not occur again for thirty years, no pains should be spared to secure the best possible observations. The most useful observations that can be made by amateurs are those which will serve to determine the number of meteors visible per hour throughout the entire duration of the shower. Circular No. 31 was accordingly distributed last year, and numerous valuable observations were thus secured from observers in all parts of the world. The results, some of which are given below, are now being discussed by Professor W. H. Pickering, and will be published later in the Annals. Similar observations are desired this year, and it is hoped that they may be made on November 15, and also on the two preceding and following evenings. The most important time for observation is from midnight until dawn, as comparatively few meteors are expected earlier. Observations are particularly needed at hours when they cannot be made at the observatories of Europe and America. In general, the time required for ten or more meteors to appear in the region covered by the accompanying map, should be recorded. This observation should be repeated every hour or half hour. If the meteors are too numerous to count all those appearing upon the map, the observer should confine his attention exclusively to some small region such as that included between the stars μ Ursae Majoris, 40 Lyncis, δ and α Leonis. If the meteors occur but seldom, one every five minutes, for instance, the time and class of each meteor should be recorded. Also, note the time during which the sky was watched and no meteors seen, and the time during which that portion of the sky was obscured by clouds. Passing clouds or haze, during the time of observation should also be recorded. The date should be the astronomical day, beginning at noon, that is, the date of early morning observations should be that of the preceding evening. Specify what time is used, as Greenwich, Standard, or Local Time. When a meteor bursts, make a second observation of its light and color, and when it leaves a trail,

record the motion of the latter by charting the neighboring stars, and sketching its position among them at short intervals until it disappears, noting the time of each observation. If the path of a meteor is surely curved, record it carefully upon the map.

On November 14, 1898, thirty-four photographs were obtained of eleven different meteors. Their discussion has led to results of unexpected value. The greatest number of meteors photographed by one instrument was five. Only two meteors were photographed which passed outside of the region covered by the map, although the total region covered was three or four times as great. No meteors fainter than the second magnitude were photographed.

Photographs may be taken, first, by leaving the camera at rest, when the images of the stars will trail over the plate and appear as lines, or secondly, attaching the camera to an equatorial telescope moved by clockwork, when a chart of the sky will be formed, in which the stars will appear as points. A rapid-rectilinear lens is to be preferred in the first case, a wide-angle lens in the second. The full aperture should be used, and as large a plate as can be covered. The most rapid plates are best for this work; they should be changed once an hour, and the exact times of starting and stopping recorded. Care should be taken to stiffen the camera by braces, so that the focus will not be changed when the instrument is pointed to different portions of the sky, especially if the lens is heavy. If the first method is employed, the position of the camera should be changed after each plate, so as to include as much as possible of the region of the map on each photograph. If pointed a little southeast of ϵ Leonis, the radiant will reach the centre of the field about the middle of the exposure. A watch of the region should also be kept, and the exact time of appearance and path of each meteor as bright as the Pole Star should be recorded. The plates should be numbered on the film side with a pencil, and should be sent to this Observatory with accompanying notes and other observations. After measurement here, they will be returned if desired. The value of the results will be much increased if similar photographs can be obtained by a second camera from ten to forty miles distant, and preferably north or south of the other.

EDWARD C. PICKERING.

September 18, 1899

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR NO. 46.

POSITION OF NOVA SAGITTARII.

The method of determining the precise positions of the stars from measures of their photographic images, described in the *Annals*, Volume XXVI, p. 237, is now generally employed here when accurate positions are desired. The positions of the planet Eros on the photographs described in Circulars Nos. 36 and 37 are being determined by this method. As an illustration of the accuracy readily attained, measures were made of the New Star in Sagittarius described in Circular No. 42. The first pair of plates measured were enlargements of Plate B 21319, taken with the 8-inch Bache telescope on April 29, 1898, with an exposure of 10 minutes. The star was then of the eighth magnitude. The second pair of plates were enlargements of Plate C 11827, taken with the 11-inch Draper telescope on March 20, 1899, when the star was of the eleventh magnitude. Six exposures of 10 minutes each were given to the last plate, moving it slightly in declination after each. Six adjacent images of the Nova and of each of the comparison stars were thus obtained. A single enlargement, therefore, furnishes six independent determinations of the position of the Nova. It was found more convenient, however, to take the mean of the measures of the six images and treat them like a single observation. Two enlargements were made of each of the two original negatives, taking care to move the reticule about a millimetre in each coördinate after the first enlargement of each plate, and thus eliminate, or at least reduce, errors in ruling. Four independent determinations of position are thus obtained, which are given below. Two positions of this object have been published, derived from visual observations. The first, by Professor O. C. Wendell, is given in Circular No. 42; the second, by Professor E. Hartwig, is given in the *Astron. Nach.*

149. 29. It should be stated that in the first of these determinations the times were noted on a chronometer by a comparatively inexperienced recorder, and in the second case, a single comparison star, $-13^{\circ}5194$, was used whose position was taken from Weisse, and differs several seconds from the recent observations of its position made here. The photographic determinations depend on the positions of five stars, $-13^{\circ}5183$, $-13^{\circ}5185$, $-13^{\circ}5194$, $-13^{\circ}5197$, and $-13^{\circ}5200$, measured with the Harvard Meridian Circle.

Wendell,	R. A. 1900 = $18^{\circ} 56' 12''.2$	Dec. 1900 = $-13^{\circ} 18' 16''$
Hartwig,	" " = $18 56 12.69$	" " = $-13 18 22.3$
B 21319, I,	" " = $18 56 12.82$	" " = $-13 18 12.6$
" II,	" " = $18 56 12.90$	" " = $-13 18 12.8$
C 11827, I,	" " = $18 56 12.81$	" " = $-13 18 13.2$
" II,	" " = $18 56 12.79$	" " = $-13 18 13.3$

The close agreement of the four photographic measures indicates that this method gives results of an accuracy at least equal to the best meridian circle observations. As in the case of other Novae, there is no evidence of proper motion, or change of position as the star fades.

Several measures were made of each image of the Nova. A comparison of them shows that the probable error of a single setting is $\pm 0''.13$, the largest residual being $0''.3$. A similar determination from settings of the comparison stars gave the probable error derived from successive settings $\pm 0''.08$. In three cases only did successive settings differ more than half a second, and these gave the values, $1''.0$, $0''.7$ and $0''.6$.

The results of the first measures of the position of the Nova, as derived from the six images of Plate C 11827, and expressed in seconds of arc, differ from their mean in x by $+0''.02$, $-0''.08$, $-0''.38$, $+0''.09$, $+0''.27$, and $+0''.07$, and in y by $-0''.48$, $-0''.32$, $+0''.18$, $+0''.36$, $-0''.08$, and $+0''.26$. The second measures similarly gave in x , $-0''.28$, $+0''.03$, $-0''.04$, $+0''.06$, $+0''.35$, and $-0''.09$, and in y , $-0''.45$, $-0''.03$, $+0''.12$, $+0''.19$, $-0''.08$, and $+0''.14$. A part of these differences is real and is perhaps due to a change in orientation of the plate when it was moved. Thus, the largest value, $-0''.48$, has nearly the same value, $-0''.45$, in the second measure. The designations of the five comparison stars, their assumed right ascensions and declinations for 1890, and their residuals in x and in y , as derived from the two measures of the two plates, are given below.

DM.	R.A. 1890.			Dec. 1890.			x				y			
	h	m	s	h	m	s	$''$	$''$	$''$	$''$	$''$	$''$	$''$	$''$
-13 5183	18	54	58.19	-13	8	36.4	+0.1	+0.2	-0.1	-0.3	+0.4	+0.3	+0.2	+0.2
-13 5185	18	55	1.90	-13	28	31.1	+0.2	-0.1	+0.5	-0.1	-1.5	-1.2	-0.6	-0.6
-13 5194	18	56	1.58	-13	24	37.6	-0.3	+0.3	+1.1	+1.3	+3.2	+2.7	+1.6	+1.6
-13 5197	18	56	26.58	-13	19	8.0	-1.8	-1.8	-2.0	-1.8	-1.4	-1.1	-1.4	-1.3
-13 5200	18	56	41.60	-13	19	25.1	+1.7	+1.4	+0.4	+0.7	-0.7	-0.5	+0.3	+0.2

EDWARD C. PICKERING.

September 23, 1899.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 47.

MME. CERASKI'S SECOND ALGOL VARIABLE.

Another remarkable variable star of the Algol class has been discovered by Mme. Ceraski, and is announced in the *Astron. Nach.* **151**, 223. The position for 1900 is R. A. = $19^h 42^m.7$, Dec. = $+32^{\circ} 28'$. From an examination of the Draper Memorial photographs of this star, it appears that while the star has its full brightness on 45 of them, on several of the early photographs it is so faint that they must have been taken when the star was near minimum. The Moscow photographs furnish the means of determining the period from an interval of four years, the Harvard photographs increase this interval to nine years. The following table gives, in the first seven lines, the results derived from the Harvard photographs; the next four, the results of the Moscow photographs; and the last line gives the estimate of M. Blajko. The times of minima as found by Professor Ceraski may be expressed by the formula J. D. $2,415,004.971 + 6^d.0065 E$. Measures of four Harvard photographs when the star had its full brightness gave the photographic magnitudes, 11.00, 10.80, 10.74, and 10.79; mean 10.83. The value of E, derived from the above formula; the year, month, and day; the Greenwich Mean Time of the middle of the exposure; the corresponding time expressed in Julian Days and decimals; and the duration of the exposure in minutes are given in the first five columns of the table. The sixth column gives the photographic magnitude, and the seventh, the phase computed by means of the formula mentioned above. The error in the ephemeris is given in the eighth column, and is derived from an approximate light curve. It appears that the period is too long by about $0^m.6$, and if this correction is applied, the errors have the values given in the ninth column. The tenth column gives the mean photographic magnitude, during the entire time of exposure, derived from the corrected ephemeris and light curve.

E.	Date.			G. M. T.		J. D.	Ex.	Magn.	Phase.	O-C.	O-C'.	C.M.
	<i>y</i>	<i>m</i>	<i>d</i>	<i>h</i>	<i>m</i>		<i>m</i>					
-580	1890	6	2	16	32	1521.689	27	11.81	+4.88	+25	+01	11.7
-570	1890	8	1	14	20	1581.597	13	12.75	+3.31	+24	+02	12.7
-570	1890	8	1	14	57	1581.623	20	12.22	+3.57	+16	-06	12.5
-557	1890	10	8	11	53	1659.495	10	<12.4	+1.15	.	.	12.8
-508	1891	8	8	16	07	1953.672	20	<11.7	+0.03	.	.	12.1
-443	1892	9	2	14	44	2344.614	16	10.96	+5.22	+18	.00	11.0
-325	1894	8	11	15	07	3052.630	10	10.90	-2.28	+13	-01	10.9
-257	1895	9	24	10	11	3461.424	102	<12	+1.24	.	.	12.9
-254	1895	10	12	6	45	3479.281	300	<12	-0.39	.	.	12.5
-97	1898	5	12	10	12	4422.425	105	<12	+0.85	.	.	12.9
-84	1898	7	29	10	22	4500.432	125	<12	+0.08	.	.	12.9
-0	1899	12	16	3	33	5005.106	125	Ft.	+1.35	.	.	12.5

It appears from this table that while the formula of Professor Ceraski satisfies all the later observations, it is not confirmed by the early observations. For instance, according to this formula the star should have had nearly its full brightness on the first three photographs. On the other hand, all the observations are satisfied by the corrected formula, in which the period is $6^d 0^h 8^m$.S. As soon as we obtain accurate observations of subsequent minima, these combined with the photographs taken in 1890, will give a much more precise formula. A comparison of the sixth and tenth columns shows that the observed and computed magnitudes differ in one case only by more than one tenth. A slight defect partially covers the image of the variable on the second plate taken August 1, 1890, and thus renders the measured value too bright. The period differs so little from exactly 6 days that for a long time the minima cannot be observed in certain longitudes. Accordingly, while valuable observations may be obtained next autumn in Europe, or better still in Asia, minima cannot be observed in America until the following year.

Five stars of the Algol class, S Cancri, U Cephei, W Delphini, +45°3062, and the star here discussed are especially interesting, owing to the large variation in their light, which amounts to about two magnitudes in each case. It is remarkable that two of these were found by Mme. Ceraski, and one by her distinguished husband.

EDWARD C. PICKERING.

February 12, 1900.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 48.

A PHOTOGRAPHIC SEARCH FOR AN INTERMERCURIAL PLANET.

It has not been, in general, the policy of the Harvard College Observatory to send expeditions to observe total eclipses of the Sun. First, since in case of cloudy weather, no return is obtained for the expenditure of a sum of money which is often large. Secondly, if clear, the results in many cases are only a series of pictures of the corona and protuberances which add but little to our knowledge of them. Therefore, when officers of this Observatory have observed eclipses, it has generally been largely at their own expense. When, however, a new problem presents itself some aid is rendered from the funds of the Observatory, in the construction of instruments and for similar expenses. The following plan for observing the Eclipse of May 28, 1900, has been prepared by Professor W. H. Pickering:—

It is a fact capable of demonstration, that the faintness of a star that may be photographed with a given instrument, against a bright background of sky depends, within certain limits, directly on the length of the focus of the lens, and is independent of its aperture.

In the Harvard Observatory Annals, Volume XVIII, p. 104, it was shown that if the place in which to look for the pole star is known, that three minutes after it first becomes visible to the naked eye in the evening, the light of the sky in its immediate vicinity is of about the same photographic intensity as that of the sky surrounding the Sun at the time of a total solar eclipse.

Starting with these two fundamental facts, a series of experiments has been undertaken with a photographic lens having an aperture of 3 inches, and a focal length of 11 feet 4 inches. The curves adopted were those employed in an ordinary landscape lens, and it was found that the field was large enough to cover nine 8×10 photographic plates arranged in three rows of three each. This result was only obtained, however, by attaching the plates to the interior of a concave surface of double curvature, and thus obtaining a curved field.

By giving an exposure of one minute in the region of the pole, with this instru-

ment, three minutes after the pole star first became visible, it was found that the light of the sky was sufficient to darken the plate appreciably, but not so much as to prevent stars of the eighth magnitude appearing with sufficient intensity to be found by a careful search, in the larger part of the field of view.

Three similar lenses have now been ordered, and the four will be placed upon one mounting, in such a manner as to photograph a region extending for sixteen degrees on either side of the Sun, and having a breadth of ten degrees throughout its length. Throughout nineteen degrees of its length every portion of the region will appear upon two separate plates.

The satellites of Mars, Jupiter, and Saturn all revolve very nearly in the equatorial planes of their primaries, and in the same manner Mercury revolves very nearly in the equatorial plane of the Sun, which is inclined about seven degrees to the plane of the ecliptic. It is, therefore, reasonable to suppose that bodies still nearer to the Sun would revolve in the same plane. It so happens that the Earth passes through this plane about one week after the date of the solar eclipse of next May, so that there is a strong probability that if an intermercurial planet exists, it will appear somewhere upon the narrow line forming the projection of this plane upon the celestial sphere. It will be seen, therefore, that the date of this eclipse is especially favorable for the proposed search.

We have very good evidence, from the visual observations hitherto made, that no intermercurial planet brighter than the third or fourth magnitude exists. We possess no evidence whatever for or against the existence of fainter bodies in this region having sufficient size to be properly called planets. We are reasonably certain that the immediate vicinity of the Sun is filled with countless bodies of such size as to be properly described as meteors.

If we assume that at its average brightness, Mercury is of the first magnitude, and that the albedo of an intermercurial planet is the same as that of Mercury, we shall find that at the distance of Mercury from the Sun, a body of the eighth magnitude would be 120 miles in diameter. If its distance from the Sun was but one half as great, its diameter would be 60 miles, and if but one quarter as great, or 9,000,000 miles, it would be 30 miles in diameter. Judging by the analogous case of Jupiter, the existence of such a small planet is quite possible.

Should such a body exist, and should it appear upon the plates, which it is proposed to expose somewhere in the State of Alabama, we should still be entirely at

a loss to compute the orbit, or to determine the distance of the body from the Sun. If, however, other photographs of it should be obtained with a similar apparatus, in Spain or Algeria, we should then be enabled to compute an approximate orbit, based on the assumption that it moved in a circular path. It might then be found again at the following eclipse, which occurs a year later, and a more accurate elliptical orbit could be computed for it. While it is desirable that the duplicate apparatus should also be furnished with four lenses, this is not necessary, and in case the planet should be found upon our plates, two lenses, one photographing the region on each side of the Sun, would be all that would be necessary to independently make the discovery, and furnish the elements necessary to compute the circular orbit. It is in the hope of inducing some European observer to supply himself with this apparatus, that the present article has been written.

The foregoing plan appears to be of sufficient importance to justify aid from the Observatory. Preparations have, therefore, been made to give it a careful trial. It is hoped that this early publication may permit similar observations to be made at a second station sufficiently distant to reduce the danger of failure from clouds, and if an intermercurial planet should be found, to furnish an approximate determination of the form of its orbit.

EDWARD C. PICKERING.

February 13, 1900.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 49.

OPPOSITION OF EROS IN 1900.

The opposition of Eros during next autumn will afford opportunities for observations of especial interest. The near approach of the planet to the Earth will permit the solar parallax to be determined, while the great variations in phase and distance will give unusual value to photometric observations obtained at this time. The ephemeris of Dr. Millosevich, published in the Berlin Jahrbuch for 1902, provides the means for discussing the measures of position of Eros. The annexed table, which is based on this ephemeris, furnishes a part of the material required for the investigations mentioned above. The date is given in the first column. The right ascension and declination for 1855, for Berlin midnight, are given in the second and third columns. This epoch is selected for convenience in identifying Eros by comparison with the stars in the Durchmusterung. The daily motions in right ascension, expressed in seconds of time, and in minutes of arc when reduced to the equator, are given in the fourth and fifth columns. The daily motion in declination, and the total motion expressed in minutes of arc, are given in the sixth and seventh columns. These quantities are important in planning observations for parallax, especially those made photographically. The logarithm of the distance from the Sun has been kindly furnished by Dr. Millosevich and is given in the eighth column. The logarithm of the distance from the Earth is given in the ninth column. From this it appears that its distance when nearest the Earth is less than a third of that of the Sun from the Earth. This minimum occurs on December 26, nearly two months after opposition, which takes place on October 30. The phase angle between the Sun and Earth, as seen from Eros, is given in the tenth column. There are few asteroids for which this angle much exceeds 30° . In the table, beginning with the value $37^\circ.5$ it gradually diminishes to $28^\circ.3$ at about the time of opposition, and then gradually increases, until on January 31, it attains the extraordinary value of $56^\circ.1$, becoming even greater later. The photometric magnitude, neglecting the phase and assuming that the light is inversely proportional to the squares of the distances of the Earth and

the Sun, is given in the eleventh column. It is based on the measures described in H. C. O. Circular No. 34, from which it appears that the magnitude would be 11.39 at a distance of unity from the Sun and Earth, and that the photographic magnitude is 0.6 fainter than the photometric. It will be noticed that these last values are nearly 0.8 fainter than those given by Dr. Millosevich, who based his magnitudes on visual observations. As the magnitude 9.5 in the Durchmusterung is about 10.5 on the photometric scale, this difference is readily explained. The difference becomes still greater if we apply a correction for phase. This correction, in the case of the asteroids, is about $0.03 p$, in which p is the phase angle. If we assume that this law can be applied to Eros for angles as great as 56° we obtain the corrected magnitudes given in the twelfth column. The phase angle in the observations described in Circular No. 34 is $21^\circ.2$. The magnitude at distance unity, therefore, becomes $11.39 - 0.64 = 10.75$. The approximate mean time of meridian transit is given in the thirteenth column, and the aberration time in the fourteenth.

EPHEMERIS OF EROS.

Date.	R. A.		Dec.		Daily Motion.				log r.	log Δ .	Phase.	Magn.	C. Magn.	M. Tr.			Aberr.
	1900-'01.	1855.	1855.		R. A.	R. A.	Dec.	Tot.						h	m	s	
		<i>h m</i>	<i>° ' "</i>	<i>s</i>		<i>° ' "</i>	<i>° ' "</i>				<i>°</i>						
Sept. 1	2	18.9	+33	27	+ 70	+15	+22	25	0.1830	9.9088	37.5	11.85	12.33	15	39	404	
9		27.5	+36	25	+ 60	+12	+22	25	.1761	.8692	36.6	11.62	12.08	15	16	369	
17		34.6	+39	26	+ 45	+ 9	+23	25	.1688	.8285	35.4	11.38	11.80	14	52	336	
25		39.2	+42	29	+ 25	+ 5	+23	24	.1613	.7871	34.0	11.13	11.51	14	25	305	
Oct. 3		40.8	+45	30	- 1	0	+22	22	.1535	.7456	32.5	10.89	11.23	13	55	278	
11		38.7	+48	20	- 32	- 5	+20	21	.1455	.7048	31.0	10.64	10.93	13	21	253	
19		32.0	+50	52	- 68	-11	+17	20	.1374	.6654	29.6	10.40	10.65	12	43	231	
27		20.6	+52	49	-101	-15	+12	19	.1291	.6286	28.6	10.18	10.40	12	0	212	
Nov. 4		5.7	+53	55	-121	-18	+ 5	19	.1207	.5954	28.3	9.97	10.18	11	14	196	
12	1	49.3	+54	0	-120	-18	- 3	18	.1124	.5666	29.1	9.79	10.02	10	26	184	
20		35.0	+53	0	- 92	-14	-11	18	.1041	.5430	30.9	9.63	9.92	9	40	174	
28		25.8	+51	2	- 45	- 7	-18	19	.0961	.5248	33.6	9.49	9.86	8	59	167	
Dec. 6		23.5	+48	22	+ 9	+ 2	-22	22	.0884	.5117	36.8	9.39	9.85	8	25	162	
14		28.2	+45	16	+ 60	+11	-24	26	.0812	.5033	40.2	9.31	9.88	7	58	159	
22		39.3	+41	56	+106	+20	-26	33	.0746	.4994	43.7	9.26	9.93	7	38	157	
30		56.0	+38	31	+143	+28	-26	38	.0686	.4994	47.0	9.23	10.00	7	23	158	
Jan. 7	2	17.1	+35	7	+172	+35	-26	44	.0636	.5029	49.8	9.22	10.07	7	13	159	
15		41.6	+31	43	+194	+41	-25	48	.0595	.5101	52.2	9.24	10.17	7	6	161	
23	3	8.6	+28	23	+210	+46	-25	52	.0566	.5210	54.3	9.28	10.27	7	1	165	
31		37.3	+25	7	+219	+50	-24	55	.0548	.5353	56.1	9.34	10.38	6	58	171	

As an example of the use of this table let us consider the most favorable conditions for determining the solar parallax. It soon appears that this problem is by no means a simple one. If we select the end of December, when Eros is nearest the Earth, we find that meridian transit occurs so early in the evening that Eros cannot be photographed far east of the meridian. Moreover, the motion both in right ascension and declination is so great that if the telescope is made to follow the stars, Eros will trail so rapidly over the plate that it may not leave any impression on it. If the total diurnal motion is $24'$, the motion will be $1''$ a minute. If, then, the diameter of the image is $2''$, Eros cannot be photographed, unless an exposure of two minutes is sufficient. In such a case it may be necessary to make the telescope follow on Eros and not on a star. All the stars will then appear as short trails which are easily bisected. If the motion of Eros is large, its position with relation to the comparison stars will differ greatly when east and when west of the meridian. Moreover, it will be necessary to measure the total motion and after subtracting the large motion of Eros determine the small remaining parallax. During the latter part of January, Eros culminates at nearly the same time on successive nights and will thus be favorably situated for observations west of the meridian for several weeks. The path of Eros has a loop extending over about 13° in right ascension and 20° in declination, and with a centre at about R. A. $2^h 5^m$, Dec. $+51^\circ$. The point of crossing is at R. A. $2^h 21^m.9$, Dec. $+34^\circ 25'$ (1855). It is, therefore, not far from the stars $+34^\circ 447$, magn. 9.3, and $+34^\circ 448$, magn. 8.0. Eros will pass through the point of crossing on September 3, 1900, and again on January 8, 1901. Photometric observations, if made on these dates, will have especial value, since the same comparison stars can be used for both.

A photograph of Eros was obtained on September 6, 1898, with the 11 inch Draper telescope, whose focal length is 153 inches. Stars of the ninth magnitude are readily photographed with this instrument in 5 seconds. The exposure was 10 minutes, the daily motion $18'$, and the computed magnitude 12.1. Allowing for the difference in motion it would be equally difficult to photograph Eros on this date and on September 17, 1900.

EDWARD C. PICKERING.

February 14, 1900.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR NO. 50.

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MEASUREMENT OF PHOTOGRAPHIC INTENSITIES.

The comparison of various celestial and terrestrial sources of light has for many years been a subject for investigation by the officers of this Observatory. One of the first comparisons of the light of the Sun and Moon was made by Professor George P. Bond in 1861 (*Mem. Amer. Acad.* VIII, N. S., p. 298). Comparisons of the light of the solar corona, of the Moon, and of twilight, with a standard candle were made by the writer in 1870. A comparison of various artificial lights was made by Professor W. H. Pickering, as his graduating thesis in 1879 (*Proc. Amer. Acad.* XV, 236). Since 1887, all the photographs obtained with the principal instruments of this Observatory have had an image of a standard light photographed on them for purposes of comparison. In 1887, when Mr. W. H. Pickering was placed in charge of the Boyden Department, an important part of his work was a quantitative determination of photographic intensities. This investigation was completed in 1891, and the results are published in the *Annals*, Volume XXXII, Chapter I. The relative brightness of 10,498 stars, for the wave length 430, was determined by Mrs. Fleming and was published in 1890 in the *Draper Catalogue* (*Annals*, Volumes XXVI and XXVII). An independent determination of the total photographic brightness of the stars was undertaken in 1896 by photographing stars out of focus. As none of these investigations served to determine certain constants, which seemed to the writer to be important, a more extensive investigation was assigned to Mr. Edward S. King, under whose direction the photographs are taken at Cambridge. This work has been modified and extended by Mr. King, so that it now includes the following researches, which he describes below : —

In 1896, a monthly test of plates was inaugurated, which was of a routine character. A complete determination, not only of the sensitiveness of the emulsion, but of the constancy of the light and of the developer employed, is obtained by the expenditure of one 8×10 plate per month (*Photogram*, VI, 261). The means of the results of these tests, extending over a long period of time and necessarily subject to all the accidental errors due to season or other factors, will probably show the effect of

the age of the plate on its sensitiveness, whether the image is affected by the interval between the exposure and the development, and other facts of similar interest.

About the same time with the above, the Director suggested that an extensive investigation be undertaken of the photographic measurement of various sources of light. The work was to be systematized into a routine, which should occupy the least time in making the observations. By extending the period over years and by performing each experiment under the most diverse circumstances, the final results should be of great accuracy. Preliminary to this work, an apparatus was constructed for making photographic wedges in which equal intervals of the scale corresponded to equal differences in stellar magnitude. The general design was the same as that described in the *Annals*, Volume XXVI, 6, except that the triangular aperture was replaced by an aperture bounded by a logarithmic curve. The part of the curve extending to minus infinity, but enclosing a finite area, is represented by admitting light through an additional aperture of equivalent area. This apparatus, having a range in aperture of five magnitudes, is useful for measuring the intensity of surfaces directly, or of bright objects, when the aperture is covered with porcelain. It is also of value in comparing the sensitiveness of plates, and for studying the relation of the darkening of the film to the exposure, and to the intensity of the light.

The object of this investigation is to determine the photographic intensity of various sources of light upon a uniform scale. This scale will be that of the Meridian Photometer, in which α Ursae Minoris has the magnitude of 2.15, and one unit corresponds to the ratio of 2.518, whose logarithm is 0.400. Luminous points may be compared directly with stars. In the case of surfaces, the light emitted by a circle having a diameter of one minute of arc is employed. In general, different portions of the same photographic plate are exposed for a given time to the sources of light to be compared, and the darkening measured with a photographic wedge.

Observations of surfaces will include, intensity of the sky at different distances from the Sun; the sky in the zenith during twilight, on clear and cloudy days, on dark and moonlight nights; comparisons of blue sky with cumulus cloud; intensity of Milky Way, Aurora, and Zodiacal Light. For this purpose pinhole cameras are used with various apertures. For very faint lights, apertures subtending an angle of 60° or more are used. When possible, automatic devices are employed, both to make the exposure and to shift the plate.

For measuring luminous points, the light concentrated by a lens illuminates the

plate placed at various distances from the focus. In this manner, bright stars, the planets, and the Moon at different phases and altitudes, may be compared with α Ursae Minoris or an artificial light placed at a distance. It is also necessary to determine the effect of any slight fogging before, after, or during the principal exposure. The total and local absorption of the lens will also be measured. The same objects are also compared directly by pinhole cameras. In using a pinhole camera to measure points differing greatly in brightness the duration of the exposure must be varied. This necessitates a study of the darkening of the plate with relation to time. The comparison is made, in all cases, with a light, producing an equal darkening in the same time. Another factor may be introduced by inclining the plate. An angle of 60° is equal to a diminution of one half, or about three quarters of a magnitude. The exact amount corresponding to the inclination used, must be determined by experiment.

The determination of the light of the Sun is a difficult problem. The light may be reduced by a distant lens of short focus, and compared with the standard light similarly reduced, but at less distance. Another way is by a combination of lenses like a telescope, which enlarges or reduces objects, as we look through one end or the other. The absorption of the instrument is thus eliminated. Two plates of glass, placed so as to give multiple reflections, will also afford a wide range of exposure, as well as a means of comparing lights of great difference in intensity. Pinhole cameras having the aperture covered with a porcelain plate can be constructed so as to give a range of 15 to 20 magnitudes, which is sufficient for comparing the Sun and the Moon. A second pinhole camera placed in front will cut off the light of the sky from the aperture. The absorption and the diffusing power of the porcelain plate must be measured independently. In all the preceding plans the sensitiveness of the plates to different colors affects the results. By combining a slit spectroscope with the cameras just described, a comparison of the light of the Sun and the Moon may be made in different parts of the spectrum, corresponding to given wave lengths.

The comparison of the spectrum of the various sources of light possesses many advantages. The work is placed on such a basis that the results are freed from the troublesome questions of absorption, sensitiveness of the plate, etc., and are rendered directly comparable with those that may be obtained at different times, by other observers, under widely differing circumstances. In fact, the results should be the same as those obtained by the eye, the bolometer, or in any other manner that may

be devised. All these measures may be made either with a telescope and objective prism, or with a slit spectroscope combined with a pinhole camera or telescope. With the objective prism the spectra are made of the same width, either by interposing a cylindrical lens, by moving the plate at the same equable rate for each exposure, or by throwing the image out of focus. In the latter case, a rectangular aperture should be placed over the prism, so as to give width with a minimum loss of definition. With the moving plate, a variation of light is obtained by covering one half of the prism at a time, along a line perpendicular to its edge.

The standard light used is an ordinary Argand gas burner shining through a small hole. The star α Ursae Minoris is made the ultimate standard to which all work is referred, since the standard light is compared with it before and after each monthly test of the plates. In addition to the wedges for measuring the density of photographic plates a polarizing photometer is used for comparing surfaces with each other.

Early in 1900, while this work was in progress, Mr. W. H. Pickering, in preparing to observe the Solar Eclipse of May 28, desired to select a suitable plate and developer for the work, and accordingly undertook the following investigation, which he describes below : —

A suitable standard of light has long been wanted in photography. Artificial sources usually give even more uncertain results photographically than they do visually, because a slight variation in temperature will effect the blue end of the spectrum even more than the red end. In 1893 it occurred to the writer to employ as a primary standard of actinic intensity the radiation of a star shining directly upon the photographic plate, without previously passing through or being reflected from any medium, except our atmosphere. Since this standard is too faint for general use, a secondary one to be standardized from it has been devised. The light from the star is condensed through a simple plano-convex lens of 8.2 cm. aperture and short focus, and is focused on a small circle of ground glass 0.5 cm. in diameter. This is placed 3 cm. in front of the sensitive plate, which is exposed to it through a small square aperture measuring 0.2 cm. on a side, cut in a blackened brass plate. The constant of this instrument was determined, and it was found to give about thirty times the light of the direct radiation of a star upon the photographic plate. With twenty minutes exposure α Ursae Minoris darkened the plate sufficiently to produce the "Sensitive Tint," that is to say the tint where a small variation in the

light is most noticeable. The secondary standard, however, is not sufficiently brilliant for ordinary purposes, and a tertiary one has therefore been devised. This consists of a box 30 cm. in length, one end of which contains an aperture 5 cm. in diameter, covered by a piece of ground glass, and the other end carries the sensitive plate and the blackened brass plate described above. Just inside the ground glass may be placed diaphragms ranging from 0.04 to 4.0 cm. in diameter. At a distance of about 200 cm. beyond the ground glass is placed an Argand gas burner. This apparatus gives ample light for all photographic purposes, and the plates exposed in it may always be standardized when necessary by an additional exposure to the secondary standard.

The three pieces of apparatus above described are adapted to various investigations. Thus the photographic brightness of the Moon, and of the brighter stars and planets, may be measured with accuracy by employing different apertures in front of the lens of the secondary standard, and measuring the brightness of the various images obtained by means of a photographic wedge, or a series of standard squares of varying density. It is very important to vary the aperture rather than the time of exposure, since the results obtained in the latter case would have to be corrected by the "time Correction" (Annals, Volume XXXII, 20). The secondary standard also enables us to express the sensitiveness of a plate, in terms of universal application throughout all time. Thus the Seed plate No. 27 is capable of being appreciably darkened when exposed for ten minutes to a source equal to 300 times the brightness of α Ursae Minoris. This amount of light is equal to about thirty times the brightness of a star whose photographic magnitude is 0.0. The logarithm of this number, 1.5, may be conveniently used to represent the sensitiveness of the Seed plate. By the use of the secondary and tertiary standard, together with an ordinary photographic telescope, we may make a study of the brightness of nebulae, comets and other luminous surfaces.

From these various investigations it is hoped that we shall obtain a scale of photographic intensities with which all sources of light may be compared and to which they may be referred.

EDWARD C. PICKERING.

May 9, 1900.

THE ASTRONOMICAL OBSERVATORY

OF

HARVARD COLLEGE.

EDWARD C. PICKERING, DIRECTOR.

CIRCULARS

51 TO 100

CAMBRIDGE:

Published by the Observatory

1905.



TITLES OF CIRCULARS.

Nos. 51 to 100.

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52. VARIABLE STARS IN CLUSTERS. RATE OF INCREASE OF LIGHT June 18, 1900.
53. COÖPERATION IN OBSERVING VARIABLE STARS January 16, 1901.
54. SIXTY-FOUR NEW VARIABLE STARS January 24, 1901.
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69. GRANT FROM THE CARNEGIE INSTITUTION. SUSPECTED PROPER MOTION OF $-1^{\circ} 3359$.
MME. CERASKI'S ALGOL VARIABLE, 20,1902. ANDERSON'S VARIABLE, 18,1902.
MISSING ASTEROIDS January 26, 1903.
70. NOVA GEMINORUM BEFORE ITS DISCOVERY April 3, 1903.
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77. FIRST SUPPLEMENT TO CATALOGUE OF VARIABLE STARS March 22, 1904.
78. VARIABLE STARS IN THE NEBULA OF ORION March 23, 1904.
79. SEVENTY-SIX NEW VARIABLE STARS May 26, 1904.
80. SIX NEW VARIABLE STARS May 26, 1904.

TITLES OF CIRCULARS.

81.	NOTES ON VARIABLE STARS OF LONG PERIOD	May 30, 1904.
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83.	COMMON'S 60-INCH TELESCOPE	August 18, 1904.
84.	CARNEGIE GRANT OF 1903	August 24, 1904.
85.	THE ANONYMOUS GIFT OF 1902	August 27, 1904.
86.	THE NEBULA OF ORION	September 5, 1904.
87.	THE NINTH SATELLITE OF SATURN. A NEW VARIABLE IN HERCULES	September 12, 1904.
88.	A NEW ALGOL VARIABLE, —15° 4905	October 7, 1904.
89.	THE NOVEMBER METEORS OF 1904	November 26, 1904.
90.	105 NEW VARIABLE STARS IN SCORPIUS.	December 8, 1904.
91.	SIXTEEN NEW VARIABLE STARS IN SAGITTARIUS	December 8, 1904.
92.	STARS HAVING PECULIAR SPECTRA	December 21, 1904.
93.	THE 24-INCH REFLECTING TELESCOPE	March 13, 1905.
94.	VARIABILITY OF EUNOMIA (15)	April 8, 1905.
95.	BRIGHTNESS OF JUPITER'S SATELLITES	April 11, 1905.
96.	843 NEW VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD	April 12, 1905.
97.	BRUCE PHOTOGRAPHS OF PLANETS	April 20, 1905.
98.	STARS HAVING PECULIAR SPECTRA. SPECTRA OF KNOWN VARIABLES.	May 5, 1905.
99.	A PROBABLE NEW STAR, RS OPHICHI	May 15, 1905.
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23.	Figure.	LIGHT CURVE OF U PEGASI.
29.	Figure.	METHOD OF DISCOVERING VARIABLE STARS OF SHORT PERIOD.
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41.	Figure 1.	LIGHT CURVE OF U VULPECULAE.
..	Figure 2.	“ “ “ ST CYGNI.
57.	Figure 1.	REGION OF NOVA PERSEI, No. 2. February 19, 1901.
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..	Plate.	SPECTRUM OF NOVA PERSEI, No. 2, February 22, February 24, 1901, AND NOVA AURIGAE, February 5, 1892.
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67.	Figure 1.	LINNÉ DURING TOTAL ECLIPSE.
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HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 51.

POSITIONS OF EROS (433) IN 1893, 1894, AND 1896.

Approximate positions of Eros (433) during the oppositions of 1894 and 1896 will be found in Circulars, Nos. 36 and 37. Since then, the photographs from which these positions were derived have been measured by the method described in the Harvard Annals, Vol. XXVI, p. 237, and reduced by the method of Turner. The measurements have been made by Miss E. F. Leland, and the reductions by Miss A. Winlock aided by Miss I. E. Woods. These photographs were taken with the Bruce, Bache, and Draper photographic doublets, whose apertures are 60, 20, and 20 cm., and the focal lengths such that 1 mm. equals 60", 179", and 163", respectively. Photographs taken with these instruments are designated by the letters A, B, and I, respectively. The smaller instruments photograph a field 10° square, and as some of the images fall near the corners of the plate it was not supposed that positions could be determined from them with a high degree of accuracy. In some cases, the images are more than 5° from the centre of the plates and are consequently much distorted, the greatest diameter exceeding a minute of arc; yet, as will be seen below, the accuracy of the places does not greatly differ from that ordinarily obtained with meridian circles. The most remarkable conclusion to be derived from these observations is that if, in the future, any other object like Eros should be discovered, we have at this Observatory the means of tracing its path since 1890, during the time in which it was moderately bright, with nearly as great accuracy as if a series of observations had been taken of it with a meridian circle.

In the following table the designation of the original negative is given in the first column. The date, the Greenwich Mean Time of the middle of the exposure, and the duration of the exposure, are given in the next three columns. Two enlargements, on a scale of 0.1 cm.=10", were made from each of these negatives, and their designations are given in the fifth column. The number of catalogue stars on these enlargements used to determine the constants of the plates, such as errors of scale, orientation, etc. is given in the sixth column. The standard coordinates of Eros are

given in the seventh and eighth columns, and the resulting right ascension and declination for 1875, in the ninth and tenth columns. The two measures of each plate are

POSITIONS OF EROS.

Plate.	Date.	G. M. T.	Exp.	Enl.	St.	X	Y	R. A. 1875.	Dec., 1875.	Δ R. A.	Δ D.		
	<i>y</i>	<i>m</i>	<i>d</i>	<i>h</i>	<i>m</i>	"	"	<i>h</i>	<i>m</i>	<i>s</i>	"		
I 9801	1893	10	28	21	55	14	6441	9 - 9627.2	-15941.0	5 58 48.11	+53 39 46.8	+0.03	-0.1
							6442	9 - 9626.9	-15941.2	5 58 48.14	+53 39 46.7		
I 9832	1893	10	30	20	18	10	6377	9 + 9760.3	-14440.0	6 4 33.13	+54 6 25.8	+0.03	-1.3
							6378	9 + 9760.7	-14441.3	6 4 33.16	+54 6 24.5		
I 9862	1893	10	31	21	21	15	6391	7 - 10903.8	+ 3653.4	6 7 37.42	+54 20 11.2	+0.40	+2.2
							6392	7 - 10900.1	+ 3655.3	6 7 37.82	+54 20 13.4		
I 10095	1893	11	26	20	26	17	6390	7 - 15368.2	+ 4066.2	7 17 31.35	+57 49 34.0	-0.29	-1.0
							6389	7 - 15370.6	+ 4065.5	7 17 31.06	+57 49 33.0		
I 10215	1893	12	19	18	21	14	6375	4 + 10544.4	+ 5340.3	7 45 56.41	+54 38 39.2	+0.28	+0.1
							6376	4 + 10546.8	+ 5340.5	7 45 56.69	+54 38 39.3		
I 10280	1893	12	23	19	49	13	6416	4 - 10591.8	- 642.9	7 45 57.59	+52 58 16.4	-0.19	-1.7
							6417	4 - 10593.7	- 644.5	7 45 57.40	+52 58 14.7		
I 10321	1893	12	27	17	32	10	6383	7 + 10580.3	+ 10362.3	7 44 43.17	+50 55 0.2	+0.03	-0.6
							6382	7 + 10580.7	+ 10361.7	7 44 43.20	+50 54 59.6		
I 10469	1894	1	19	16	57	10	6408	7 - 654.1	-15761.6	7 26 28.40	+28 45 48.4	-0.20	+0.9
							6409	7 - 656.7	-15760.7	7 26 28.20	+28 45 49.3		
I 10559	1894	1	25	16	16	13	6393	9 - 3564.4	+ 11541.9	7 23 33.46	+21 14 58.0	-0.01	-1.0
							6394	9 - 3564.6	+ 11541.0	7 23 33.45	+21 14 57.0		
A 222	1894	2	5	15	26	60	6410	7 - 4630.1	+ 5011.8	7 23 17.83	+ 8 45 22.8	-0.05	+1.9
							6411	7 - 4630.8	+ 5013.7	7 23 17.78	+ 8 45 24.7		
A 246	1894	2	16	14	49	12	6414	8 + 1059.4	- 9589.6	7 29 58.55	- 0 21 42.7	-0.08	+0.6
							6415	8 + 1058.2	- 9589.0	7 29 58.47	- 0 21 42.1		
I 10685	1894	2	16	14	59	13	6436	11 + 10997.4	-13093.8	7 29 59.01	- 0 21 54.4	-0.32	-3.6
							6437	11 + 10992.6	-13097.4	7 29 58.69	- 0 21 58.0		
B 10909	1894	4	16	14	13	10	6371	7 + 2201.3	+ 13823.8	9 17 0.62	-13 33 54.0	-0.03	+1.8
							6374	7 + 2200.9	+ 13825.6	9 17 0.59	-13 33 52.2		
B 10951	1894	4	18	14	29	10	6365	9 + 8489.9	+ 12761.3	9 21 47.01	-13 38 52.7	-0.10	+1.3
							6370	9 + 8488.5	+ 12762.6	9 21 46.91	-13 38 51.4		
B 11174	1894	5	19	14	16	10	6344	7 + 7170.1	-10985.5	10 38 1.88	-14 57 21.9	+0.10	+3.6
							6346	7 + 7171.6	-10981.9	10 38 1.98	-14 57 18.3		
B 15531	1896	4	6	20	52	60	6360	7 - 7958.9	- 3771.5	18 36 59.92	-38 32 48.8	+0.03	+1.0
							6361	7 - 7958.6	- 3770.5	18 36 59.95	-38 32 47.8		
B 16108	1896	6	4	16	40	70	6350	5 - 10686.4	- 9103.3	18 30 6.81	-40 2 45.2	+0.75	+0.2
							6351	5 - 10677.8	- 9102.7	18 30 7.56	-40 2 45.0		
B 16157	1896	6	5	19	54	10	6355	5 + 15242.6	+ 8861.3	18 27 51.27	-39 58 33.0	+0.24	+0.7
							6357	5 + 15245.4	+ 8861.9	18 27 51.51	-39 58 32.3		
B 16165	1896	6	5	22	4	11	6353	4 + 1306.6	- 8891.1	18 27 39.55	-39 58 2.1	+0.07	+3.4
							6354	4 + 1307.4	- 8887.7	18 27 39.62	-39 57 58.7		
B 16518	1896	6	29	19	17	15	6348	9 - 9732.7	+ 4124.9	17 37 43.91	-36 21 26.7	-0.09	+1.4
							6349	9 - 9733.9	+ 4126.3	17 37 43.82	-36 21 25.3		
A 1876	1896	6	30	13	46	60	6413	6 + 5864.8	+ 4719.0	17 36 22.23	-36 11 20.9	0.00	+0.5
							6412	6 + 5864.8	+ 4719.4	17 36 22.23	-36 11 20.4		

independent, except for errors in the original negatives and in the method of reduction. The differences in the two results for the right ascension, and for the declination, are given in the last two columns.

On 19832, the image is irregular. The position of the brightest part is given. The centre precedes it $0^s.66$, and is $8''.6$ south. On A 222 and A 1876, the images are much elongated, owing to the motion of Eros. The means of the measures of the ends are given. The discordance in the positions derived from I 10685 and B 16108 is probably due to the poor quality of the images.

A complete discussion of these measures, including the original settings and the results for each comparison star, is in course of preparation for the Annals. The positions of the stars have been taken from the Catalogues of the Astronomisches Gesellschaft, except in the case of the plates taken in 1896 for which the Cordoba Catalogues have been used. The average value of the 296 residuals for the catalogue stars is, for x , $\pm 1''.03$, for y , $\pm 1''.06$. The average difference of the standard coordinates of the two positions of Eros is, for x , $\pm 1''.8$, for y , $\pm 1''.4$. For the three Bruce plates these values become $\pm 0''.6$, and $\pm 1''.0$, respectively.

EDWARD C. PICKERING.

June 7, 1900.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 52.

VARIABLE STARS IN CLUSTERS. RATE OF INCREASE OF LIGHT.

It appears from Circular No. 33, that the proportion of stars, found to be variable, in the cluster Messier 3, N. G. C. 5272, is greater than in any other object of the same class. This object is, however, so low at Arequipa, and the stars are so faint, that satisfactory photographs cannot be obtained of it, with the 13-inch Boyden refractor, with exposures of less than 90^m . The rate of increase of the light of many of these stars is extremely rapid, and in order to determine this change with the greatest precision, photographs having very short exposures are necessary. Accordingly, at my request, Professor James E. Keeler has taken a series of admirable photographs of the cluster with the 3-foot Crossley reflector of the Lick Observatory. These photographs were taken on May 20 and 21, 1900. The first plate had an exposure of 60^m , the others, 24 in number, exposures of 10^m each. Professor Bailey, from an examination of these photographs, has derived the following results:—

Three variable stars have already been measured on these plates. They are Nos. 11, 96, and 119. The series of plates extended from $17^h 42^m 46^s$ to $20^h 24^m 11^s$, on the night of May 20, and from $17^h 2^m 38^s$ to $20^h 53^m 27^s$, May 21, G. M. T. These periods of time covered the entire interval from minimum to maximum, for each of the above stars, on at least one night. The same stars were also measured on 49 plates made at Arequipa during the years 1895–1899. From a study of all these measures the periods have been determined as follows: for No. 11, $12^h 12^m 25^s$; for No. 96, $12^h 0^m 15^s$; for No. 119, $12^h 24^m 31^s$. For the following discussion of the rate of increase, however, only plates made by Professor Keeler on the night of May 21, and having exposures of 10^m were used.

The measures of the brightness of the variables were made by Argelanders's method, using a sequence of comparison stars, whose magnitudes have not yet been determined. The results are therefore given in grades. The value of one of these grades is somewhat uncertain, but is not far from one tenth of a

CIRCULAR NO. 52.

magnitude, since in previous work by the same observer the value of one grade was found to be 0.085 of a magnitude. The observations were plotted, using vertical distances to represent magnitudes and horizontal distances, time. A smooth curve was then drawn through them. The time scale employed in the drawing was very open, in order to read with greater accuracy the ordinates of the curve corresponding to intervals of 5^m. The results of the measures are very accordant. For all the measures on the Lick plates of 10^m exposure, the average deviation from the curve is less than half a grade. The results for the three stars, for the period of increase of the light, are given below. The first column contains the time, and the second, the corresponding brightness expressed in grades. The differences, found by subtracting each value in the second column from that following it, are given in the third column, which therefore represents, in each case, the change in light during an interval of five minutes.

INCREASE OF LIGHT.

VAR. No. 11.			VAR. No. 96.			VAR. No. 119.		
Time.	Gr.	Diff.	Time.	Gr.	Diff.	Time.	Gr.	Diff.
<i>h. m.</i>			<i>h. m.</i>			<i>h. m.</i>		
18 20	0.0	0.0	19 30	0.0	0.0	17 25	0.0	0.0
25	0.0	0.3	35	0.0	0.4	30	0.0	0.6
30	0.3	0.8	40	0.4	1.1	35	0.6	1.0
35	1.1	1.2	45	1.5	1.7	40	1.6	1.2
40	2.3	1.4	50	3.2	2.1	45	2.8	1.4
45	3.7	1.6	55	5.3	2.4	50	4.2	1.5
50	5.3	1.8	20 0	7.7	2.5	55	5.7	1.5
55	7.1	1.9	5	10.2	2.3	18 0	7.2	1.5
19 0	9.0	1.9	10	12.5	1.8	5	8.7	1.4
5	10.9	1.9	15	14.3	1.2	10	10.1	1.3
10	12.8	1.8	20	15.5	0.7	15	11.4	1.2
15	14.6	1.5	25	16.2	0.4	20	12.6	1.2
20	16.1	0.8	30	16.6	0.1	25	13.8	1.0
25	16.9	0.4	35	16.7	0.0	30	14.8	0.9
30	17.3	0.2	40	16.7	..	35	15.7	0.7
35	17.5	0.0	..	..	..	40	16.4	0.4
40	17.5	..	..	..	..	45	16.8	0.2
..	..	..	..	..	..	50	17.0	0.0
..	..	..	..	..	..	55	17.0	..

From this table it appears that the total increase of light, amounting to 17.5 grades, takes place in the case of Variable No. 11 within 70^m ; in the case of No. 96, an increase of 16.7 grades occurs within 60^m ; and No. 119, 17.0 grades, within 80^m . The maximum increase, during any interval of 5^m , is, in the case of No. 11, 1.9 grades; No. 96, 2.5 grades; No. 119, 1.5 grades. During 30^m No. 11 increases in light 10.9 grades, or at the rate of 21.8 grades per hour; No. 96, 12.8 grades, or at the rate of 25.6 grades per hour; and No. 119, 8.6 grades, or at the rate of 17.2 grades per hour. The greatest rapidity is in the case of No. 96, which increases, during 5^m , at the rate of 30 grades, or at least two and a half magnitudes per hour, and during 30^m at the rate of more than two magnitudes per hour. This rate of change appears to be the most rapid of any known variable. The Algol variable U Cephei, which perhaps undergoes the most rapid change of any star not found in clusters, changes at the rate of about one and a half magnitudes per hour, during the half hour of its most rapid increase and decrease. The total times of increase for the three stars, 70^m , 60^m , and 80^m , are 10, 8, and 11 per cent, respectively, of their entire periods. Near the beginning and end of increase, however, the rate of change seems to be relatively slow. If we allow one and a half grades for each of these periods of slow change, making three grades in all, we find that the remaining increase, amounting to more than four fifths of the whole change in light, takes place for the three stars in 42^m , 34^m , and 54^m , respectively, that is, in about 6, 5, and 7 per cent of the respective full periods. In the case of No. 96, this increase is about ten times as rapid as the corresponding decrease. In general, it may be stated that the length of periods and the form of light curves are similar to those of many of the variables in Messier 5, and in ω Centauri. (Astrophysical Journal, Vol. X, 255). It will be noted that the periods of these three stars in Messier 3 are about one half a day. Several other variables in this cluster appear to have approximately the same period.

EDWARD C. PICKERING.

JUNE 18, 1900.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 53.

COÖPERATION IN OBSERVING VARIABLE STARS.

The number of known variable stars of long period is now so great, and is increasing so rapidly, that the observation of many of them has been greatly neglected. Observations by Argelander's method are so easily made that they are especially adapted to observers who, for various reasons, cannot use precise photometric methods. In the case of variables of small range, including those of short period and many of the Algol variables, the subjective errors greatly diminish the value of observations by Argelander's method. In these cases, also, the periods and light curves appear to be so regular that continuous observations are not needed. It appears to be better to observe such objects photometrically throughout their variation, if possible, and thus determine the light curves. Small variations in the period can then be determined by occasional observations at times when the light is varying most rapidly. Many of the variables of long period appear to change irregularly, and continuous observations are required until the nature of the changes are known. Moreover, the range is, in many cases, so great that the errors of observation are not sufficient to affect seriously the form of the curve. The method of observations for these stars, which has been in use here for the last twelve years is as follows:—A sequence of comparison stars is first selected as near the variable as possible, and each about half a magnitude brighter than the next in order, the brightest being somewhat brighter than the variable at maximum, and the faintest, fainter than the variable at minimum. Care is taken not to include double stars or those near brighter stars. The stars brighter than the tenth magnitude are then measured with the meridian photometer. This has been done for nearly all of the comparison stars selected here. Magnitudes determined with the meridian photometer, for all stars of the seventh magnitude and brighter, can now be furnished upon a uniform system. For the fainter stars, measures have been made of large numbers of stars as faint as the thirteenth magnitude, and photometers are now in use with which the faintest stars visible in the largest telescopes can be measured. As the apparent magnitude may sometimes differ from the measured magnitude, it has been found best to estimate

independently on several nights the interval between each of the adjacent stars in the sequences, and adopt magnitudes found by combining these estimates with the photometric magnitudes. Having thus provided standards of comparison on the same scale for stars in all parts of the sky, a variable may be compared on any night with the stars nearest it in brightness in its sequence, taking care to select one that is brighter and another fainter. From estimates of these intervals in grades, the light of the variable is readily reduced to the standard scale. When a variable is faint, it is impossible to observe it for several days every month, near the time of full Moon. At least one observation should be obtained in the interval between successive times of full Moon. This can only be done for polar stars, owing to the proximity of the Sun at certain seasons. Since the periods of a large portion of the variables of long period exceed half a year, it is evident that monthly observations will, in general, give a good idea of the form of the light curve. Of course, additional observations should also be obtained, but failure to secure any observation during a long interval should be avoided if possible. Since 1889, an attempt has been made to observe seventeen circumpolar variables, north of declination $+50^\circ$, at least once a month. These stars are always above the horizon at Cambridge, so that they can be observed at all seasons. The results for the years 1889-1899 will be found in Volume XXXVII, Part I, of the *Annals*, which is now printed and in process of distribution. Similar observations have been made of about sixty other variables, but less regularly. At Arequipa, similar observations have been made of a large number of southern variables. It is much to be desired that all variables of long period should be observed in the same way, or at least so that all can be reduced to a uniform scale of magnitudes. Coöperation is necessary to attain success in this work. Variables near the ecliptic can be observed when near the Sun much better at tropical stations than at those near the pole. The reverse is true for polar variables. Northern variables can be observed for a longer portion of the year at northern observatories, and southern variables at southern observatories. When a variable can be observed only in the morning it is much more likely to escape observation than at other seasons. A computation has been made of the date on which the variables mentioned above are 20° above the horizon at Cambridge at midnight, and also in the morning and evening when the Sun is still 10° below the horizon. Thus, these three dates for the star, *T Andromedæ*, are July 1, May 1, and March 12. Accordingly, from May 1 to July 1, this star can be observed only in the morning, from July 1 to March 12 it can be observed in

the evening, while from March 12 to May 1 observations are difficult owing to twilight. When a variable is bright it is best observed with a small telescope, that is, one having an aperture of not more than 6 or 8 inches. Observations of great value could be obtained by an observer with a large telescope if he was notified when the star was too faint to be observed with smaller instruments. The excellent charts of Father Hagen are almost indispensable for observing the stars when fainter than the ninth magnitude. When the variables are bright, the need has been felt here for charts on a smaller scale and covering a larger region. After various experiments, photographic enlargements have been made of portions of the admirable charts of the Bonn Durchmusterung. A region 3° square, surrounding each variable, has been enlarged three times, thus giving a map on the standard scale of one minute of arc to one millimetre. The stars on these maps, while appearing coarse by daylight, are thus easily seen and identified at night without using a light bright enough to dazzle the eye. The designations of the stars in the sequence are marked upon these enlargements, and copies will be furnished at cost. Charts will be furnished free of cost to experienced observers who are ready to coöperate in the above plan of work. Observations of nearly equal value can be obtained by those unaccustomed to estimating intervals in grades. It is only necessary to enter on the charts the standard magnitudes of the comparison stars, and from these to estimate directly the magnitude of the variable. Charts are now being prepared, and with the corresponding magnitudes can soon be furnished for the following stars:—

T Andromedæ, T Cassiopeiæ, R Andromedæ, S Ceti, S Cassiopeiæ, R Piscium, R Arietis, α Ceti, S Persei, R Ceti, U Ceti, R Tauri, R Aurigæ, U Orionis, R Lyncis, R Geminorum, S Canis Minoris, R Cancri, V Cancri, S Hydræ, T Hydræ, R Leonis Minoris, R Leonis, R Ursæ Majoris, X Virginis, R Comæ Berenices, T Virginis, R Corvi, Y Virginis, T Ursæ Majoris, R Virginis, S Ursæ Majoris, U Virginis, V Virginis, R Hydræ, S Virginis, R Canum Venaticorum, S Boötis, R Camelopardalis, R Boötis, S Libræ, S Serpentis, S Coronæ Borealis, R Herculis, R Scorpis, S Scorpis, U Herculis, V Herculis, R Ursæ Minoris, R Draconis, S Herculis, R Ophiuchi, T Herculis, R Senti, R Sagittarii, R Cygni, χ Cygni, S Cygni, RS Cygni, R Delphini, U Cygni, V Cygni, T Aquarii, R Vulpeculæ, T Cephei, S Cephei, SS Cygni, S Aquarii, R Pegasi, S Pegasi, R Aquarii, and R Cassiopeiæ.

If the above plan proves successful, it is hoped that it may be extended to the other variable stars of long period.

EDWARD C. PICKERING.

JANUARY 16, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 54.

SIXTY-FOUR NEW VARIABLE STARS.

THE photographs of the Henry Draper Memorial continue to furnish great numbers of new variable stars. A large part of those enumerated below were found from the presence of bright hydrogen lines in their spectra. Many stars whose spectra are of the fourth type also prove to be variable. These variables have been divided into two classes. First, those in which the variation is so great that it is obvious to the most inexperienced observer. Secondly, those in which the variation so far detected is small, about half a magnitude to a magnitude. In each of these cases, two or more experienced observers, who are accustomed to accurate measures of photographic brightness, are satisfied that the change is real. We have here a case like the confirmation visually by a second observer, since so many plates of each variable are examined, generally a dozen or more, that on several the star is bright, and on several, faint. There seems to be no way in which these changes can be rendered more evident, and owing to the redness of many of the stars it is doubtful if visual observations would be more conclusive. Perhaps photometric measures, which appear to be less influenced by color, or photographs taken with a reflector might be employed to advantage. Owing to the accidental errors, additional measures add but little to the certainty of variation, which is best shown by comparing two plates, on one of which the variable is bright, on the other, faint. It seems best therefore to publish the positions of these stars, hoping that by further observations the laws governing their changes may be learned. In both tables, the name of the constellation is given in the first column. For northern stars, the boundary of the constellations is taken from the Atlas Cœlestis Novus of Heis, and for southern stars from the Uranometria Argentina. The catalogue designation, if any, is given in the second column. The approximate right ascension and declination for 1900 are given in the third and fourth columns. The class of spectrum is given in the fifth column. Following the notation of the Draper Catalogue, Mc is used to denote a spectrum of the third type like that of α Ceti at minimum. Md denotes a similar spectrum in which, however, the hydrogen lines are bright as in α Ceti at maximum. Inter-

mediate spectra are indicated by Mc 5 d. N denotes a spectrum of the fourth type, and Pec. that the spectrum is peculiar. The name of the discoverer is given

TABLE 1.
VARIABLES HAVING LARGE RANGE.

Constellation.	Designation.	R. A. 1900.		Dec. 1900.		Class.	Discoverer.
		<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>		
Chamaeleon	Z. C. 8 ^h 2054	8	24.1	-76	2	Md	W. P. Fleming
Carina		9	18.2	-68	20	Md	W. P. Fleming
Vela	A. G. C. 13539	9	51.3	-41	7	N	L. D. Wells
Antlia	A. G. C. 14440	10	30.8	-39	3	N	L. D. Wells
Cariua		10	33.2	-61	48	....	E. C. Pickering
Centaurus	Z. C. 11 ^h 129	11	2.9	-54	35	N	L. D. Wells
Virgo	-18° 3660	13	36.3	-18	38	....	L. D. Wells
Lupus	Z. C. 14 ^h 3225	14	52.6	-53	0	N	W. P. Fleming
Lupus		15	8.5	-50	25	....	E. C. Pickering
Circinus		15	20.0	-57	22	Md?	W. P. Fleming
Norma	Z. C. 16 ^h 59	16	2.6	-48	58	Md?	W. P. Fleming
Norma	A. G. C. 21999	16	9.0	-52	21	Md?	W. P. Fleming
Norma	-51° 10147	16	17.7	-51	42	N	W. P. Fleming
Triang. Austr.	Gilliss 12037	16	39.8	-67	36	N	W. P. Fleming
Scorpius	-43° 11672	17	18.1	-43	44	Md	W. P. Fleming
Scorpius	-35° 11923	17	40.8	-35	40	N	W. P. Fleming
Ophiuchus	-6° 4661	17	44.8	-6	40	....	W. P. Fleming
Ara	-48° 12145	17	47.3	-48	17	Md	W. P. Fleming
Ara	-49° 11810	17	49.2	-49	46	Mc	W. P. Fleming
Corona Austr.	-39° 12196	17	58.2	-39	20	N	W. P. Fleming
Corona Austr.		18	2.6	-45	26	Mc	W. P. Fleming
Corona Austr.		18	7.2	-42	53	Md	W. P. Fleming
Telescopium		18	19.0	-49	42	Md	W. P. Fleming
Sagittarius	-16° 4904	18	24.6	-16	59	N	W. P. Fleming
Scutum	-8° 4726	18	44.9	-8	1	N	L. D. Wells
Scutum	-8° 4764	18	50.0	-8	19	N	W. P. Fleming
Sagittarius		18	55.9	-12	54	Md	W. P. Fleming
Sagittarius	-22° 4958	18	57.7	-22	51	Mc	W. P. Fleming
Telescopium		19	0.5	-49	4	Md	W. P. Fleming
Telescopium	C. P. D. -50° 11027	19	10.5	-50	38	Md?	W. P. Fleming
Lyra	+42° 3338	19	22.2	+42	36	....	W. P. Fleming
Telescopium		19	43.1	-50	15	Md	W. P. Fleming
Telescopium		20	11.2	-52	56	Md	W. P. Fleming
Telescopium	-51° 12487	20	12.9	-51	1	Mc 5 d	W. P. Fleming
Cygnus		21	35.7	+42	45	....	H. R. Colson
Aquarius	-22° 5901	22	17.7	-22	35	Md?	W. P. Fleming
Piscis Austr.	A. G. C. 30605	22	20.5	-29	35	....	W. P. Fleming
Andromeda	+48° 4093	23	28.8	+48	16	Md?	W. P. Fleming
Pegasus	+25° 5054	23	55.0	+25	21	Md?	W. P. Fleming

in the sixth column. A few remarks on individual stars follow Table II. Each is preceded by the right ascension for 1900.

TABLE II.
VARIABLES HAVING SMALL RANGE.

Constellation.	Designation.	R. A. 1900.	Dec. 1900.	Class.	Discoverer.
		<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>		
Hydrus		2 10.4	- 71 57	Me 5 d	W. P. Fleming
Hydrus	A. G. C. 2634	2 26.3	- 69 58	Me 5 d	W. P. Fleming
Cetus	A. G. C. 2859	2 37.4	- 23 2	Me 5 d	W. P. Fleming
Horologium	Z. C. 2 ^h 1104	2 41.2	- 54 44	Me	W. P. Fleming
Eridanus	- 1° 546	3 46.4	- 1 41	Me 5 d	W. P. Fleming
Puppis	A. G. C. 8954	7 1.7	- 35 47	Me 5 d	W. P. Fleming
Canis Major	- 11° 1805	7 3.4	- 11 46	N	W. P. Fleming
Lynx	+ 46° 1271	7 20.9	+ 46 10	Me	W. P. Fleming
Hydra	- 8° 2343	8 19.6	- 8 11	Me 5 d	W. P. Fleming
Hydra	- 9° 2612	8 34.9	- 9 11	Me 5 d	W. P. Fleming
Virgo	- 8° 3329	12 15.2	- 8 27	Md?	W. P. Fleming
Centaurus	A. G. C. 17944	13 6.3	- 56 28	....	L. D. Wells
Virgo	- 2° 3653	13 8.9	- 2 16	Me 5 d	W. P. Fleming
Chamaeleon	A. G. C. 18352	13 24.6	- 77 3	....	W. P. Fleming
Lupus	Z. C. 14 ^h 970	14 16.9	- 47 4	N	W. P. Fleming
Norma	- 50° 10442	16 14.6	- 50 14	Md	W. P. Fleming
Serpens	- 15° 1923	18 13.6	- 15 39	N	W. P. Fleming
Corona Austr.		18 23.7	- 45 2	Md	W. P. Fleming
Telescopium	- 48° 12910	19 0.1	- 48 44	Me	W. P. Fleming
Sagittarius	- 16° 5360	19 28.6	- 16 35	N	L. D. Wells
Sagittarius	C. P. D. - 41° 9189	19 40.6	- 11 26	Me 5 d	W. P. Fleming
Sagittarius	A. G. C. 27520	20 0.8	- 27 31	Me 5 d	W. P. Fleming
Octans	(Gilliss 15580)	22 5.7	- 85 10	Me 5 d	W. P. Fleming
Aquarius	- 18° 6299	23 19.2	- 17 52	Pec.	W. P. Fleming
Cassiopeia	+ 56° 3111	23 49.4	+ 56 56	Pec.	L. D. Wells

h. *m.*

7 20.9. The variation, although small, has been confirmed by two other observers, and is indicated by observations with the meridian photometer.

10 33.2. Found by superposing an original negative on a contact print from another negative taken on a different date.

15 8.5. Found by superposing an original negative on a contact print from another negative taken on a different date.

17 40.8. This star is C. P. D. - 35° 7243. Innes has announced the variability of - 35° 7270, which follows 51° 9, south 0°.1. A. J. 20, 59, 95.

18 44.9. "Probably a variable of the 19 Piscium type" in Espin's Catalogue of Red Stars. Cunningham Memoirs, No. V, 75. Discovered also, independently by Mrs. Fleming.

h. *m.*

19 22.2. Found by inspection of a photograph taken as described in Circular No. 29. 13 exposures of 29^m 40^s each were made on July 13, 1899, stopping the clock automatically for 20^m after each exposure. This variable is mentioned in the Fifty-fourth Annual Report. Photometric measures show that its maxima are represented by the formula, $J. D. 2,414,856^m.500 + 0^m.5668 E$. Range 0.83 magnitudes.

21 35.7. Discovered visually during observations of 88 Cygni.

23 49.4. This star is ρ Cassiopeia. The variation although small, has been confirmed by four other observers. The spectrum closely resembles that of the second type.

Measures have been made of a number of the stars in the above tables and also of those announced without magnitudes in previous circulars. The right ascension and declination for 1900, the number of plates examined, and the brightest and faintest photographic magnitudes, are given in the successive columns of Table III. The last column gives the authority for the variability.

TABLE III.
PHOTOGRAPHIC MAGNITUDES.

R. A.	Dec.	No.	Br.	Ft.	Authority.	R. A.	Dec.	No.	Br.	Ft.	Authority.
<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>					<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>				
2 10.4	-71 57	75	9.6	10.5	Table II	16 54.3	-54 55	50	9.9	11.0	Circular 24
2 37.4	-23 2	68	7.7	8.6	Table II	17 34.7	-57 40	43	8.3	9.8	Circular 24
6 28.1	- 8 48	54	9.0	10.1	Circular 32	17 45.7	-51 40	56	8.9	12.4	Circular 24
8 1.7	-38 29	47	0.3	10.2	Circular 24	17 47.3	-48 17	134	9.7	<12.3	Table I
8 3.1	-22 38	23	9.4	11.6	Circular 24	18 13.6	-15 39	...	8.5	9.1	Table II
8 24.7	- 5 59	48	8.0	9.6	Circular 24	18 19.0	-49 42	129	11.3	<12.7	Table I
8 34.9	- 9 14	70	7.7	9.0	Table II	18 23.7	-45 2	107	11.9	12.6	Table II
9 13.5	-65 49	116	10.9	12.1	Circular 32	19 10.5	-50 38	113	9.2	10.6	Table I
10 8.3	+60 31	76	7.0	8.3	Circular 32	19 22.2	+42 36	191	7.2	8.1	Table I
10 33.2	-61 48	210	10.1	<12.5	Table I	19 37.1	+32 23	58	8.7	10.3	Circular 24
11 59.6	- 5 13	77	7.2	8.8	Circular 32	20 3.3	-60 14	75	9.0	10.2	Circular 24
12 2.1	- 6 12	80	7.1	8.3	Circular 24	20 11.2	-52 56	91	10.5	12.9	Table I
13 15.1	-61 3	55	10.5	11.3	Circular 24	20 12.9	-51 1	124	8.1	9.7	Table I
14 1.7	+13 59	30	10.0	13.0	Circular 24	21 13.6	-45 27	83	7.2	8.9	Circular 24
16 17.7	-51 42	102	11.0	<12.3	Table I	23 19.2	-17 52	73	8.3	<9.4	Table II

EDWARD C. PICKERING.

JANUARY 24, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 55.

THE SPECTRUM OF ζ PUPPIS.

THE presence of a second series of hydrogen lines, in addition to the ordinary series, in the spectrum of ζ Puppis, was announced in Circulars, Nos. 12, 16, and 18. Accurate wave lengths could not then be determined for the less refrangible lines. Since then, measures have been made of six photographs of spectra of ζ Puppis, and two of spectra of δ Orionis. The measurements have been made by Miss F. Cushman, and the conversion into wave lengths, by Mr. Edward S. King, with the assistance of Miss Cannon. This work will be published in full in a later volume of the Annals. Following the notation proposed by Vogel for the ordinary series of hydrogen lines, the new series may be designated, $H\alpha'$, $H\beta'$, $H\gamma'$, etc. The great difficulty in determining the wave length of $H\beta'$, which is approximately 5414, is that no known lines of greater wave length have been found in the spectrum of ζ Puppis. Accordingly, extrapolation, which is always uncertain, must be employed. The star, δ Orionis, besides the line $H\beta'$, contains also the known line D_2 , wave length 5876, which thus permits the wave length of $H\beta'$ to be determined by interpolation. These lines also occur in ϵ Orionis, and probably in other stars of the so called Orion type. It is greatly to be desired that the spectra of these stars should be photographed with a slit spectroscope attached to a large telescope, as the wave lengths of these lines could then be determined with far greater accuracy by the help of a comparison spectrum. A comparison of the mean of the wave lengths given in Circular No. 16, with those recently determined, and with two computed values, is given in the following table. The first of these is given in Circular No. 16, and is a slight modification of Balmer's formula. It is $3646.1 \frac{n^2}{n^2 - 16}$, in which n is an even number for the ordinary series of hydrogen lines, and an odd number for the additional series. The second formula is $\frac{1}{\lambda} = A + B \frac{1}{m^2} + C \frac{1}{m}$. This form was proposed by Kayser, immediately

after the announcement of the discovery of this series of lines. If we accept this formula, it would appear to be the true law connecting their wave lengths, and would render them comparable with those of other elements. The designation of the lines is given in the first column of the following table, the mean of the observed wave lengths given in Circular No. 16 is contained in the second column, and the wave lengths derived by Mr. King in the third column. The next four columns give the value of n , taken from the sixth column of the table in Circular No. 16, the computed wave lengths taken from the seventh column of the same table, and the residuals found by subtracting the computed values from the observed values given in the second and third columns. A similar comparison with the formula $\frac{1}{\lambda} = 27461 - 121790 \frac{1}{m^2} - 352010 \frac{1}{m^4}$, is contained in the last four columns of the table.

Des.	Cir. 16.	Obs.	n .	Comp.	O-C.	O-C.	m .	Comp.	O-C.	O-C.
H α'	.....	.....	5	10128.1	..	..	3	10435.2	..	..
H β'	.....	5413.6	7	5413.9	..	-0.3	4	5413.0	..	+0.6
H γ'	.....	4542.4	9	4543.6	..	-1.2	5	4540.1	..	+2.3
H δ'	4200.6	4200.7	11	4201.7	-1.1	-1.0	6	4200.6	0.0	+0.1
H ϵ'	4026.3	4026.0	13	4027.4	-1.1	-1.4	7	4027.5	-1.2	-1.5
H ζ'	3924.8	3924.0	15	3925.2	-0.4	-1.2	8	3925.8	-1.0	-1.8
H η'	3858.6	3860.8	17	3859.8	-1.2	+1.0	9	3860.6	-2.0	+0.2
H θ'	3816.0	3815.7	19	3815.2	+0.8	+0.5	10	3815.4	+0.6	+0.3
H ι'	3783.4	.....	21	3783.4	0.0	..	11	3782.1	+1.3	..
			∞	3646.1	..	..	∞	3641.5	..	..

It will be noticed that the two computed values do not differ very greatly for any of the observed lines. The difference is greatest for H γ' , and here the observed value is nearly midway between the two computed values. On the whole, the observed values agree more nearly with the first formula, than with the second. This is remarkable, if it does not represent the true law, since this formula contains no arbitrary constants. There is only one constant, and that is determined with great accuracy from the ordinary series of hydrogen lines. The second formula contains three arbitrary constants which are selected so as to represent the observed values as nearly as possible. A least square determination was not considered necessary, since the outstanding differences from observation were

evidently systematic, and not accidental. The wave length when m or n is infinite, could be accurately measured, but unfortunately these lines, like those of the ordinary series, do not appear to be present in the stars. The wave length of the line $H\alpha'$ differs greatly according to the two formulas, but no means as yet exist for determining radiations of such great wave length in a star.

EDWARD C. PICKERING.

CAMBRIDGE, U. S., Feb. 11, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 56.

221

ANDERSON'S NEW STAR IN PERSEUS.

The cable message announcing the discovery of a new star in the constellation Perseus, by the Rev. T. D. Anderson, was received at the Observatory early in the evening of February 22, 1901. Owing to clouds, the new star was only occasionally visible, and twice it was necessary to cover the instruments on account of falling snow. During the intervals, however, various observations were made, which have a value owing to their early date. Numerous comparisons by Miss Cannon, with α Aurigae, magnitude 0.21, α Orionis, magnitude 0.92, and α Tauri, magnitude 1.06, showed that the magnitude of the star was about 0.9. Photometric comparisons, by Professor Wendell with the 15 inch telescope, of the Nova with the star +43°732, magnitude 7.25, at 14^h 0^m and at 17^h 25^m, Greenwich Mean Time, gave the magnitudes 0.35 and 0.39, respectively.

Meanwhile, an examination was being made, by Mrs. Fleming, of the photographs of the region obtained here earlier in the month, with the various instruments. Although photographs are taken with the transit photometer throughout every clear night, yet owing to twilight, they cannot be taken as early in the evening as this star culminates. Fortunately, for some weeks, the work of the transit photometer, which only photographs objects near the meridian, has been supplemented by photographs with Cooke and Ross-Zeiss Anastigmat lenses. With these instruments, an attempt is made to cover the entire sky, both east and west of the meridian, at short intervals. The completeness with which this has been done is shown by the fact that we have photographs of the region of the Nova with the Cooke lens on February 8, 18, and 19, and with the Ross-Zeiss lens on February 2, 6, 18 and 19. The photograph taken with the Cooke lens on February 19 had an exposure of 66^m, beginning at 11^h 18^m Greenwich Mean Time. While this photograph showed not only the faintest stars contained in the Durchmusterung, but also stars as faint as the eleventh magnitude, no trace of the Nova was seen. This result was confirmed by the other plates

mentioned above. A general examination of the large number of earlier plates of this region did not seem to be necessary. Plates taken with the 8 inch Bache telescope as early as November 6, November 8, and December 12, 1887, fail to show the Nova, although the spectra of stars as faint as the eighth magnitude are clearly visible on all, and those of the ninth magnitude on the plate taken on November 6. A photograph taken with the 24 inch Bruce telescope on October 18, 1894, with an exposure of 15^m , shows no trace of this object, although stars as faint as the magnitude 12.5 are well seen.

On this same evening, February 22, 18 photographs were taken with various instruments, under the direction of Mr. Edward S. King. They showed that, photographically, the Nova was 0.3 fainter than α Aurigae. The general appearance of the photographic spectrum resembled that of the Orion type and was very unlike that of other new stars, in which the bright lines are the most conspicuous feature. This star had a strong continuous spectrum traversed by 33 dark lines. The approximate wave lengths, as derived by Hartmann's formula, from the measures of $H\epsilon$, $H\gamma$ and $H\beta$, are given below. Each is followed by its relative intensity, and by the difference found by subtracting it from the wave length of the corresponding line, if any, in the spectrum of β Orionis. As the lines having greater wave length than 5000 have thus been determined by extrapolation, they may be subject to large systematic errors.

3894, 10, $H\zeta$, —5; 3970, 20, $H\epsilon$, 0; 4026, 3, 0; 4077, 2, —1; 4102, 30, $H\delta$, 0; 4126, 5, +2; 4151, 1, —4; 4266, 2, +1; 4341, 40, $H\gamma$, 0; 4366, 1, +1; 4388, 2, 0; 4415, 1; 4435, 1, +3; 4470, 2, +2; 4481, 20, 0; 4510, 2, —2; 4530, 2; 4552, 2; 4572, 1; 4616, 1; 4643, 1; 4665, 3; 4714, 3, —1; 4862, 40, $H\beta$, 0; 4885, 2; 4922, 2, 0; 5325, 1; 5399, 1; 5431, 1; 5677, 2; 5695, 7; 5719, 5; and 5761, 1. On careful examination the lines 3970, 4102, 4341, 4481, and 4862 were seen to be bright on the edge of greater wave length. The line 4665 was bright on the edge of shorter wave length, or there was a bright line whose approximate wave length was 4660. The line 4026 was not measured, but identified from its position.

On February 23, the clouds were so dense that few observations could be made. The star appeared to be brighter and bluer than α Aurigae and to have the approximate magnitude 0.0. The spectrum was photographed faintly and showed no marked change except that the line K, which was absent on the previous evening, was present and nearly as intense as $H\epsilon$.

On February 24, it became clear soon after noon, and at one o'clock the Nova was seen with the 6 inch Equatorial, and also with the 2 inch finder, in strong sunlight. In the evening, the magnitude according to visual comparisons, was 0.54, from measures with the 15 inch Equatorial, 0.59, and with the meridian photometer, in strong daylight, 0.28. Photographically it was 0.4 or 0.5 fainter than α Aurigae. The spectrum showed a remarkable change. It was traversed by numerous bright and dark bands, and closely resembled that of Nova Aurigae. The principal lines were dark with accompanying bright lines of somewhat greater wave length. The bright lines accompanying K and H ϵ were reversed, and traversed by narrow well defined dark lines. These last lines, and one of somewhat shorter wave length than H β , are the only sharply defined lines in the spectrum, all of the others being broad and hazy, and difficult to measure with accuracy.

Clouds interfered with observations on February 25, but the Nova was evidently much fainter than on the previous evening. Its magnitude from visual comparisons was 1.4, from photometric measures, 1.07. The spectrum differed slightly from that on February 24. The lines H δ , H γ , and H β were also reversed and replaced by one or more narrow dark lines.

On February 26, the magnitude from visual comparisons was 1.3, from photometric measures 1.49. The changes in the spectrum were slight.

Observations of the position of the Nova were made by Mr. J. A. Dunne, with the 8 inch meridian circle, on February 23, 24, and 25, with the result for 1900.0, R. A. $3^h 24^m 24^s.02$, Dec. $+43^\circ 33' 42''.4$.

It therefore appears that on and before February 19, 1901, the star was invisible, or at least fainter than the eleventh magnitude. On February 21, its magnitude was 2.7, according to Mr. Anderson. On February 22, its magnitude was 0.5, perhaps becoming a little brighter on February 23, and then diminishing, so that on February 25 its magnitude was 1.1. Its spectrum on February 22 and 23, was of the Orion type, nearly continuous, traversed by narrow dark lines. During the next 24 hours an extraordinary change took place, so that on February 24 the spectrum resembled that of the other Novae. It was traversed by bright and dark bands, and the principal dark lines had accompanying bright lines of slightly greater wave length.

During the last fourteen years, and since the general application of photography to astronomy, eight new stars are known to have appeared, Nova Persei in 1887; Nova Aurigae, in 1891; Nova Normae, in 1893; Nova Carinae, in 1895; Nova

Centauri, in 1895; Nova Sagittarii, in 1898; Nova Aquilae, in 1899; and Nova Persei, in 1901. The second and last of these, which were much brighter than the others, were found visually by Dr. Anderson. All of the others were found by Mrs. Fleming, from an examination of the Draper Memorial Photographs. Nova Aquilae was announced by telegraph, but has not been described in these circulars. Its position for 1900 is R. A. $19^h 15^m.3$, Dec. — $0^\circ 19'$. It was not seen on plates taken on November 1, 1898, and earlier, although stars of the thirteenth magnitude appeared on some of them. On April 21, 1899, it was seventh magnitude. It appears on eighteen photographs taken during that summer, and on October 27, 1899, it was tenth magnitude. In July, 1900, when it was discovered, it was about twelfth magnitude. Seven bright lines, H ζ , H ϵ , H δ , H γ , 4693, H β , and the nebular line 5007, were seen in the spectrum photographed on July 3, 1899. On September 7, 1899, H γ and a somewhat fainter line, which is probably 4959, were the only bright lines visible. On October 27, 1899, H γ and 5007 were alone visible and bright, so that the spectrum, had then become that of a gaseous nebula.

EDWARD C. PICKERING.

February 27, 1901.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 57.

NOVA PERSEI, No. 2.

THE early observations made here, of the new star in Perseus, are described in Circular No. 56. This star may be designated Nova Persei, No 2, to distinguish it from the star in R. A. $1^h 55^m.1$, Dec. $+56^\circ 15'$, which appeared in this constellation in 1887. A photograph of the vicinity of the Nova, taken with the Cooke lens on February 19, 1901, with an exposure of 66^m , beginning at $11^h 18^m$ G. M. T., is shown in Figure 1. For comparison, a similar photograph taken on February 26, 1901, with an exposure of 56^m , beginning at $14^h 32^m$ G. M. T., and showing the Nova, is given in Figure 2.



FIG. 1.

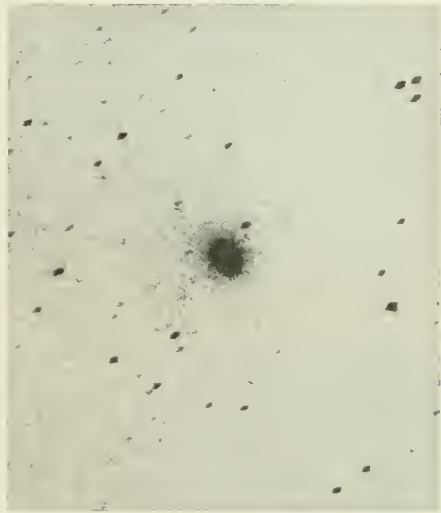


FIG. 2.

The accompanying plate gives enlargements, made with a moving plate, of three photographs of spectra taken with the 11-inch Draper telescope. The first represents the new star in Perseus taken on February 22, 1901, with an exposure



NOVA PERSEI, No. 2. February 22, 1901. Isochromatic Plate.



NOVA PERSEI, No. 2. February 24, 1901. Isochromatic Plate.



NOVA ACRIGAE. February 5, 1892. Ordinary Plate.

of 40^m , beginning at $16^h 08^m$ G. M. T. The second represents the same star taken on February 24, 1901, with an exposure of 66^m , beginning at $14^h 43^m$ G. M. T. The change from the first form of spectrum to the second must have been very sudden. A plate taken through dense clouds on February 23, with an exposure of 29^m , beginning at $11^h 37^m$ G. M. T., showed but little change, while Professor Vogel has announced that a photograph taken the same night shows a spectrum traversed by several broad, hazy bands. The third spectrum represents Nova Aurigæ, taken on February 5, 1892, with an exposure of 123^m , beginning at $11^h 09^m$ G. M. T. It will be seen that the second and third spectra closely resemble each other, but that the lines in Nova Aurigæ are much narrower and more sharply defined. The later photographs of the spectrum of the new star in Perseus show numerous changes, the dark lines and the edges of the bright lines being, in many cases, well defined.

EDWARD C. PICKERING.

MARCH 15, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 58.

VARIABILITY IN LIGHT OF EROS.

The discovery by Dr. Oppolzer that the light of Eros is variable suggests some photometric problems of great interest. If, as seems probable, we assume that the variation is due to the rotation of the planet, we can, from measures of its light determine the time of rotation, and the direction in space of the axis of rotation. Owing to the varying position of the observer with regard to the planet, much information can be obtained which is impossible in the case of a variable star.

Four corrections must be applied to the observations. First, for the velocity of light; second, for the distance of the Sun and Earth; third, for phase; and fourth, for the direction of the axis of rotation. If this axis were pointed towards the observer, no variation would be perceptible, while the range in brightness would attain its maximum value when the axis was at right angles to the line of sight. Neither of these conditions can be fulfilled exactly, since the position of the axis is probably nearly fixed, and the inclination of the orbits of Eros and the Earth would make great changes in this angle. Let p represent the complement of the altitude of the Earth above the equator of Eros, which will be equal to the angle between the axis of Eros and the direction of Eros as seen from the Earth. Let r denote the angle between the plane passing through the Earth and the axis of Eros, and any other plane passing through the axis of Eros, assumed as an origin. A most important correction depends upon r . The time of all the observations must be corrected by an amount equal to r divided by 360° and multiplied by the period of variation. As a first approximation, we may assume that the axis of Eros is parallel to that of the Earth, and that the plane passing through the vernal equinox is taken as an origin. In that case, r will equal the right ascension of Eros. As stated above, if $p = 0^\circ$ there will be no variation in light, and the range will be zero. If $p = 90^\circ$, the range will attain its maximum value. For intermediate values of p , we may assume that the range will be proportional to $\cos p$. The changes in the range may be used to determine the value of p , and from it the position of the axis of Eros. Equations may be formed in which p and r , or p alone, are the unknown quantities from which we may derive the approximate position of the axis. Besides observations at the

present time, it will be necessary to determine the light curve when Eros is in several other portions of the sky, determining the range and also the times of maximum and minimum as accurately as possible. The rapid motion of Eros renders it difficult to compare the observations on different nights, without using different, and in some cases distant, comparison stars. Fortunately, the change in light is so rapid that consecutive observations of a large part of the light curve can generally be made. The opposition of 1894 would have been particularly favorable for these studies, since the declination changed from $+57^{\circ}$ to -14° in a few months, and would thus have furnished large coefficients for determining the value of p , although, as shown below, the range seems to have been small at that time.

Assuming that the variation in light of Eros is due to its rotation, two explanations may be offered as in the case of variable stars of short period (Proc. Amer. Acad., 1881, XVI, 257). First, that Eros is darker on one side than on the other, as is probably the case with Iapetus, the outer satellite of Saturn, and secondly, that it is elongated, or double, as has been assumed by M. André and others (Astron. Nach. 155, 30). In the first case, the successive maxima would always have the same intensity, and would succeed each other at equal intervals which would be equal to the period of revolution. The same would be true for the minima. In the second case, if the two bodies differed in diameter, the successive maxima and minima might have unequal intensities, and if the orbit were elliptical the intervals between them would be alternately long and short. This seems to be the case with Eros, and the first hypothesis seems therefore improbable.

On the other hand, if the variation in light is caused by two similar bodies alternately eclipsing each other, it is difficult to see how more than half the light can be cut off in each case, and the minima more than three quarters of a magnitude fainter than the maxima. It then becomes necessary to assume that the two bodies are of unequal brightness, that they are elongated, or that we have a single body of the shape of a dumb-bell. Some observers have found the minima two magnitudes fainter than the maxima. To account for this, we should be obliged to assume that one axis of the body was six times as long as that at right angles to it. Observations show that the light of Eros is continually varying, while if the case were that of a simple eclipse, as in the stars of the Algol type, we should expect that it would retain its full brightness for a large portion of the time.

If the bodies were of the same size, and the orbit circular, it might be impossible, from the light curve, to distinguish between the two hypotheses. The fourth of the corrections mentioned above, however, furnishes a means of distinguishing between them in any case. If the body is dark on one side, the time of revolution will equal

the interval between the successive maxima, and the correction for the position of the observer will be proportional to this quantity. If then the position changes 180° , the correction will be one half the interval between the successive maxima. In the second case, the time of revolution will be double this, that is, equal to the interval between a given maximum and the next but one, so that the correction for position will now be twice as great as before, and approximately equal to the interval between the successive maxima.

Much material already exists for determining the constants mentioned above. Several of the photographs of Eros taken in 1893, 1894, and 1896, had an exposure of an hour or more. Owing to the motion of Eros, it formed a trail on each of these plates, which in some cases shows distinct variations in brightness. This was noticed when the plates were first examined, but was supposed to be due to changes in the haziness of the air. As this is an easy method of discovering the variability of an asteroid, it is hoped that astronomers engaged in a photographic search for such objects will examine carefully all trails, to detect any changes in intensity. An examination of forty-one asteroid trails photographed with the Bruce telescope, seven of them on a single plate, failed to show, except in one or two instances, any change beyond that apparently due to varying atmospheric absorption. Generally, more than one asteroid appeared on each plate, and in such cases all showed the same changes in intensity.

The photographs of Eros taken in 1893 and 1894 fail to show any marked variations in light, and it is probable that the range was, at that time, small. The first three photographs were taken on October 28, 30, and 31, 1893, and included the same region, so that Eros could be compared with the same stars on all. On the first photograph it was estimated to be 0.20 magn. fainter, and on the second 0.17 magn. fainter than on the third. The corresponding times, expressed in Julian Days and fractions following Greenwich Mean Noon, are 2,412,765.913, 2,412,767.846, and 2,412,768.890, respectively. The corrections mentioned above for velocity of light, and for the position of the Earth, have not been applied. No conclusions can be drawn from the plates taken on January 1 and 8, 1894. The plate taken on January 30, 1894, shows that the light was nearly constant during the first 30^m of the exposure. The Bruce plate taken on February 5, 1894, shows that the light was nearly constant during the first 12^m of the exposure, diminishing by about 0.4 magn. during the remainder of the exposure. A maximum is therefore indicated at about 2,412,865.622.

The plates taken during 1896 give more conclusive evidence of changes. The plate taken on April 6, showed an increase of light during the first part of the expo-

sure, and indicated a probable but somewhat uncertain maximum at 2,413,656.890. One plate was taken on June 4, and two on June 5. The first of these images was estimated to be 0.20 magn. fainter, and the third 0.83 magn. fainter than the second. The first also indicated a maximum at about 2,413,715.702. The times of the three plates were 2,413,715.694, 2,413,716.829, and 2,413,716.919. A maximum is indicated by the plate taken on June 29, at about 2,413,740.803. The Bruce plate taken on June 30, shows a probable increase, followed by a very marked decrease, and indicating a maximum at 2,413,741.561.

The photometric measures made in 1898, and described in H. C. O. Circular No. 34 (*Astron. Nach.* **147**, 363), furnish an accurate determination of the times of maximum, and of the range for that epoch.

A very large number of photometric measures of Eros have been made since July, 1900. Observations have been obtained with the 15-inch Equatorial on 51 nights, the number of photometric settings each night being, in general, 32, but sometimes more. It has also been observed on 56 nights with the 12-inch horizontal telescope, 32 or more settings being made each night. Some months will be required to reduce these observations completely, owing to delay in adopting magnitudes of the comparison stars. It is hoped, however, to issue shortly another Circular giving the results of a preliminary discussion of these observations, and of those described above.

EDWARD C. PICKERING.

APRIL 24, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 59.

SPECTRUM OF NOVA PERSEI NO.2.

The star Nova Persei, No.2, has now become so faint that its spectrum can no longer be photographed satisfactorily with a large dispersion. Moreover, it is, at sunset, so low in the northwest that it cannot be observed to advantage in the evening. A series of photographs of its spectrum, ever since its appearance, has been made with the 11 inch Draper telescope. At first, two prisms were used giving a spectrum in which the distance from $H\epsilon$ to $H\beta$ is 3.76 cm. After March 19, it was found that, owing to the diminishing light, better results could be obtained with one prism, giving a spectrum in which the distance from $H\epsilon$ to $H\beta$ is 1.80 cm. Meanwhile, a second series of spectra has been obtained with the 8 inch Draper telescope with much smaller dispersions, the distances between the lines $H\epsilon$ and $H\beta$ being 0.57 cm., and 0.14 cm., respectively. Care was taken, when the Nova was bright, to allow the spectrum to trail, or to give it a rapid motion over the plate, so that it should not be over-exposed with these small dispersions. These photographs will, therefore, be comparable with those taken when the star becomes very faint. It is expected that the spectrum can thus be studied even when the star is of the tenth magnitude or fainter, although its light will have diminished more than ten thousand times. The series of spectra taken with the 11 inch Draper telescope is now completed, unless the star should again become bright. A careful study of these photographs has been made by Miss Amie J. Cannon and will be published in the Annals. A brief summary of the results is given below. The principal bright lines are accompanied by dark lines on the edge of shorter wave length. All of the wave lengths have been referred to the centres of these bright lines, since after March 23 the dark hydrogen lines disappeared.

A description of the spectrum of Nova Persei, No. 2, as photographed here on February 22, 23, and 24, 1901, is given in Circular No. 56. Plates taken since February 24 show numerous changes. Narrow dark lines, probably due to reversal, appeared upon the bright bands, and the latter increased in intensity

with respect to the continuous spectrum. The dark bands became narrower, and, in some cases, separated into two or more parts. A peculiar dark band between $H\eta$ and $H\zeta$, and extending from 3845 to 3856, which was as intense as $H\zeta$ on February 24, faded very rapidly and was not seen after February 28. A dark band near $H\delta$, and having wave length 4056 to 4069 on February 24, showed peculiar changes in intensity, width, and wave length. The dark bands of hydrogen became double, and then grew fainter, and in place of the hazy bands two narrow, dark lines appeared. The dark band K also became double and decreased in intensity. On March 17, $H\zeta$, $H\epsilon$, $H\delta$, and $H\gamma$, each consisted of a narrow, sharply defined, dark line, and on the most careful inspection, an extremely faint component, well separated, was seen towards the violet. $H\beta$ was clearly double, the faint component being well marked. The wide dark band, K, had entirely disappeared, and a narrow dark line remained, which was only slightly more intense than the reversed K.

On March 19, there appears to have been a peculiar change in the spectrum. No dark lines were present, except the fine lines due to reversal superposed on the bright bands, and the continuous spectrum was almost invisible. The line K was absent. The plate on this date was taken with two prisms and exposed 120^m. A peculiar broadening, or displacement towards the violet, of the bright band $H\zeta$ had taken place since March 17. On March 19, this band extended more than half way to $H\eta$. On March 23, the continuous spectrum was present and narrow dark lines were seen on the edges of shorter wave length of the bright lines $H\epsilon$, $H\delta$, and $H\gamma$. Three other dark bands were present, and several bright bands besides those of hydrogen. The position of $H\zeta$ was normal. On March 27, a strong continuous spectrum was seen, but the dark components of the hydrogen bands were absent, and have not been seen since. A well marked, narrow, dark line was present at wave length 3865, and a fainter dark line at 3860. There was a hazy, dark band extending from 3806 to 3827, and a bright band from 4453 to 4489, both of which appeared to coincide with helium lines. The position of $H\zeta$ was normal. On March 30, the spectrum was like that of March 27, except that line 3865 was more intense, and 3860 was not seen. The continuous spectrum, which was very intense, was photographed far into the violet, but no lines were distinctly seen beyond a hazy, dark band which extended from wave length 3775 to 3794. The bright band 4908 to 4942 was very faint, and the band 4990 to 5040 was brighter than the magnesium band, b. On April 1, the spec-

trum was nearly the same as on March 30. Owing to a long period of cloudy weather, no good plates were obtained from April 1 to April 12, when a peculiar spectrum was photographed. $H\zeta$ appeared to be missing, and near its place, there was a bright band as intense as $H\beta$, whose centre was 3875. This band, He , and $H\delta$, were very sharply defined towards the red, and hazy towards the violet. It is of interest to note that a dark band of well marked intensity occurs in the spectrum of γ Velorum at wave length 3875. A peculiar bright line appeared in the Nova on April 12 near $H\gamma$, on the side of greater wave length. The wave length of this line is 4384, and it was quite sharply defined towards the red while the space between it and the bright band $H\gamma$ appeared somewhat like a faint bright band. On April 13, the position and intensity of $H\zeta$ were normal, and, although the plate was poor, the spectrum was not of the peculiar type of April 12. This peculiar spectrum was, however, photographed again on April 26, when the peculiarities were even more marked than on April 12. Band 3875 was the most intense bright band on April 26. Band 4990 to 5040 had also increased in intensity, while $H\delta$ and $H\beta$ had diminished. $H\gamma$ was more intense than $H\beta$. The continuous spectrum was absent. Bands 4908 to 4942, and the magnesium band, b , were not seen. On April 27, the spectrum was again normal. Band 3875 was absent, and the continuous spectrum was of well marked intensity. In general, the spectrum appeared to be like that of March 30. On April 28, the spectrum was again peculiar, and like that of April 26. The bright bands which were very sharply defined on the edge of greater wave length on April 12, were, on April 26, sharply defined on the edge of shorter wave length. When the plate taken on April 12 is superposed upon that of April 26, this difference in the definition of the bands is very striking.

On May 1 and 3, the spectrum was peculiar and like that of April 28. Photographs were attempted on May 6 and 7, but the Nova was evidently too low and the glare of sunset prevented success. Nothing is seen on the plates. It thus appears that two types of spectra have been visible* from March 19 to May 3. Photographs of the peculiar spectrum were obtained on March 19, April 12, 26, 28, May 1, and 3; of the normal spectrum on March 23, 27, 30, April 1, 13, and 27. It is interesting to note the connection between the changes in the spectrum and in the light of the Nova, for on all the dates on which the peculiar spectrum was photographed, a minimum occurred, according to the Harvard visual and photometric observations, except on April 12. The magnitude of the star was the same on April 12 and 13, while the

spectrum was different. On April 26 and 28, however, there occurred marked minima, and the peculiar spectrum was photographed on both dates, while on the intermediate evening, April 27, when the Nova was about a magnitude and a half brighter than on either the preceding or following night, the spectrum was normal.

The following table shows the connection between the spectrum and the magnitude of the Nova. The first column gives all the dates on which the Nova was successfully photographed at Harvard with the 11 inch telescope from March 17 to May 3, 1901. The second column gives the character of the spectrum. The third column gives the magnitude from visual observations reduced to the photometric scale.

RELATION OF SPECTRUM TO MAGNITUDE.

DATE.	SPECTRUM.	MAGN.	DATE	SPECTRUM.	MAGN.	DATE.	SPECTRUM.	MAGN.
Mar. 17	Normal	3.8	April 1	Normal	4.1	April 27	Normal	4.2
" 19	Peculiar	5.0	" 12	Peculiar	4.6	" 28	Peculiar	5.4
" 23	Normal	3.6	" 13	Normal	4.6	May 1	Peculiar	5.3
" 27	Normal	4.1	" 26	Peculiar	5.8	" 3	Peculiar	5.5
" 30	Normal	4.2						

THE SPECTRUM OF η CARINAE.

On April 16, 1898, Miss Cannon, while examining plates taken in Arequipa for the classification of stellar spectra, recorded the statement regarding Nova Aurigae, "Spectrum made up almost entirely of bright bands that coincide in position with those of η Carinae." This is followed by a detailed description of the spectrum of η Carinae, and a comparison with the spectrum of Nova Aurigae, including the bright and dark hydrogen lines, which is incorporated in the Remarks in the Annals, Vol. XXVIII, page 175, now in the hands of the printer. Photographs pointing out this resemblance were contained in the exhibit of the Harvard Observatory at Paris in 1900, and are now in the Buffalo Exhibition.

EDWARD C. PICKERING,

June 6, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 60.

OBJECTS HAVING PECULIAR SPECTRA.

A LIST of stars having peculiar spectra, and found by Mrs. Fleming from an examination of the Draper Memorial photographs, is given in the annexed table. The designation of the star, its approximate right ascension and declination for 1900, its catalogue magnitude, and a brief description of its photographic spectrum, are given in the successive columns of the table. The remarks following the table furnish additional details of the spectrum and, in some cases, a more accurate determination of the position as derived from a photograph, when the object is not a catalogue star.

TABLE I.
PECULIAR SPECTRA.

Design.	R. A. 1900.		Dec. 1900.		Magn.	Description.
	<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>		
. . .	0	56.0	-72	42	..	Type V. Gal. long. 268° 10', lat. -45° 15'.
. . .	1	6.2	-73	44	..	Gaseous nebula. Gal. long. 267° 29', lat. -44° 9'.
. . .	4	49.9	-69	21	..	Gaseous nebula. Gal. long. 247° 21', lat. -35° 41'.
. . .	4	52.6	-69	33	..	Gaseous nebula. Gal. long. 247° 31', lat. -35° 24'.
. . .	4	55.1	-69	21	..	Gaseous nebula. Gal. long. 247° 13', lat. -35° 14'.
. . .	4	55.7	-66	26	..	Type V. Gal. long. 243° 42', lat. -35° 50'.
. . .	4	56.8	-66	32	..	Gaseous nebula. Gal. long. 243° 48', lat. -35° 42'.
. . .	4	57.3	-66	33	..	Gaseous nebula? Gal. long. 243° 48', lat. -35° 39'.
. . .	4	57.5	-68	35	..	Gaseous nebula? Gal. long. 246° 15', lat. -35° 12'.
. . .	4	57.8	-68	33	..	Type V. Gal. long. 246° 12', lat. -35° 11'.
. . .	5	0.4	-70	20	..	Type I. H β and H γ bright.
. . .	5	3.0	-66	49	..	Type V. Gal. long. 244° 0', lat. -35° 3'.
. . .	5	10.2	-69	0	..	Type V. Gal. long. 246° 27', lat. -34° 0'.
. . .	5	10.3	-69	1	..	Type V. Gal. long. 246° 28', lat. -33° 59'.
. . .	5	13.8	-67	29	..	Type V. Gal. long. 244° 35', lat. -33° 54'.
. . .	5	14.8	-69	25	..	Type V. Gal. long. 246° 52', lat. -33° 31'.
. . .	5	22.2	-68	3	..	Gaseous nebula. Gal. long. 245° 8', lat. -33° 3'.
. . .	5	22.5	-68	4	..	Gaseous nebula. Gal. long. 245° 9', lat. -33° 1'.
. . .	5	23.9	-71	43	..	Type V. Gal. long. 249° 26', lat. -32° 25'.
. . .	5	24.6	-71	26	..	Type V. Gal. long. 249° 5', lat. -32° 24'.
. . .	5	26.4	-67	35	..	Type V. Gal. long. 244° 32', lat. -32° 42'.
. . .	5	27.1	-68	55	..	Type V. Gal. long. 246° 6', lat. -32° 31'.
. . .	5	35.6	-67	39	..	Gaseous nebula. Gal. long. 244° 32', lat. -31° 50'.

CIRCULAR NO. 60.

Design.	R. A. 1900.		Dec. 1900.		Magn.	Description.
	<i>h.</i>	<i>m.</i>	<i>o.</i>	<i>p.</i>		
. . .	5	36.2	-69	45	..	Type I. $\text{H}\beta$, $\text{H}\gamma$, and $\text{H}\delta$ bright.
. . .	5	36.8	-69	44	..	Type I. $\text{H}\beta$, $\text{H}\gamma$, and $\text{H}\delta$ bright.
. . .	5	37.6	-69	30	..	Type V. Gal. long. $246^\circ 41'$, lat. $-31^\circ 32'$.
. . .	5	37.7	-69	16	..	Type V. Gal. long. $246^\circ 25'$, lat. $-31^\circ 32'$.
. . .	5	40.7	-69	27	..	Type V. Gal. long. $246^\circ 37'$, lat. $-31^\circ 16'$.
. . .	5	40.9	-69	27	..	Type V. Gal. long. $246^\circ 37'$, lat. $-31^\circ 14'$.
. . .	5	41.4	-69	43	..	Gaseous nebula. Gal. long. $246^\circ 55'$, lat. $-31^\circ 11'$. Lines 5007, $\text{H}\beta$, $\text{H}\gamma$, $\text{H}\delta$ and $\text{H}\epsilon$ bright.
A. G. C. 8991	7	3.2	-23	41	6.3	Type I. $\text{H}\beta$ bright.
Z. C. 10^h 1363	10	19.4	-59	8	8.8	Type I. $\text{H}\beta$ bright.
Z. C. 10^h 2112	10	30.3	-47	53	9	Peculiar.
C. P. D. -58° 2845	10	49.7	-58	59	9.8	Type V. Gal. long. $256^\circ 13'$, lat. $+0^\circ 4'$.
C. P. D. -61° 2577	11	39.6	-61	43	9.9	Type V. Gal. long. $262^\circ 55'$, lat. $-0^\circ 33'$.
Z. C. 11^h 3668	11	54.8	-58	2	9	Peculiar.
. . .	13	26.4	-65	28	..	Gaseous nebula. Gal. long. $274^\circ 48'$, lat. $-3^\circ 54'$.
-17° 3961	13	50.3	-17	45	8.0	Peculiar.
-43° 9005	14	16.1	-43	41	10	Gaseous nebula. Gal. long. $287^\circ 45'$, lat. $+15^\circ 1'$.
Z. C. 14^h 970	14	16.9	-47	4	9.5	Type IV.
. . .	15	7.1	-59	28	..	Type V. Gal. long. $287^\circ 43'$, lat. $-2^\circ 35'$.
C. P. D. -65° 3171	15	46.7	-65	52	9.2	Peculiar.
-40° 11127	16	58.1	-40	44	9.9	Gaseous nebula. Gal. long. $313^\circ 11'$, lat. $-1^\circ 4'$.
. . .	17	3.5	-55	16	..	Gaseous nebula. Gal. long. $301^\circ 55'$, lat. $-10^\circ 22'$.
-49° 11366	17	14.6	-49	22	10	Peculiar. Gal. long. $307^\circ 49'$, lat. $-8^\circ 27'$.
Z. C. 17^h 1520	17	24.4	-51	0	8	Peculiar.
-33° 12168	17	26.5	-33	33	9.8	Type V. Gal. long. $322^\circ 18'$, lat. $-1^\circ 35'$.
. . .	17	33.5	-57	52	..	Peculiar.
. . .	17	38.1	-44	52	..	Gaseous nebula. Gal. long. $313^\circ 51'$, lat. $-9^\circ 27'$.
A. G. C. 24406	17	52.7	-36	0	7.2	Type V. Gal. long. $320^\circ 0'$, lat. $-7^\circ 27'$.
. . .	17	52.8	-56	16	..	Type I. $\text{H}\beta$ bright.
-43° 12354	18	5.9	-43	43	10	Peculiar.
. . .	18	11.1	-46	2	..	Gaseous nebula. Gal. long. $315^\circ 31'$, lat. $-15^\circ 7'$.
-16° 4904	18	24.6	-16	59	9.8	Type IV.
. . .	18	27.9	-22	43	..	Gaseous nebula. Gal. long. $338^\circ 27'$, lat. $-7^\circ 57'$.
-13° 5083	18	38.7	-13	20	9.1	Type IV.
-4° 4678	18	58.7	-4	28	9.0	Type V. Gal. long. $358^\circ 16'$, lat. $-6^\circ 13'$.
-9° 5069	19	11.0	-9	14	10	Gaseous nebula. Gal. long. $355^\circ 22'$, lat. $-11^\circ 7'$.
-50° 12918	20	12.9	-50	8	10	Type IV.

h. m.
0 56.0. Position for 1875, R. A. = $0^h 55^m 10^s.3$, Dec. = $-72^\circ 50' 18''$. This fifth type star is in the Small Magellanic Cloud, and is the only object of its class so far found in this region.

1 6.2. Position for 1850, R. A. = $1^h 4^m 45^s.2$, Dec. = $-73^\circ 59' 43''$. This nebula is in the Small Magellanic Cloud.

h. m.
4 49.9. This, and the following twenty-seven objects are in the Large Magellanic Cloud. The number of stars of the fifth type, in this region, is thus increased from six to twenty-one.

4 57.3. A bright line appears near $\text{H}\beta$ in the spectrum of this faint object. In such cases, the only way to decide whether the object is a gaseous nebula, a star of the

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|---|---|
| <p><i>h. m.</i>
first type having the hydrogen line $H\beta$ bright, or a star of the fifth type, is to see if the wave length of this line is greater than, equal to, or less than that of $H\beta$. This is done by superposing a chart plate of the region on a spectrum plate, so that the images of adjacent stars on the former coincide with the hydrogen line $H\beta$ in the images on the latter plate. Owing to the faintness of this object and the small dispersion, it is difficult to determine the exact position of the bright line.</p> <p>4 57.5. See 4^b 57^m.3.</p> <p>5 40.7. This object was announced as a gaseous nebula in N. G. C. 2081, Circular No. 19. An examination, by the method described above (see 4^b 57^m.3), however, shows that the spectrum is of the fifth type.</p> <p>7 3.2. The bright hydrogen line in the spectrum of this star was found by Miss Cannon.</p> <p>10 30.3. Z. C. 10^b 2112. A broad dark band in this spectrum, of somewhat shorter wave length than $H\beta$, appears to coincide with the bright band characteristic of spectra of the fifth type. In fact, the spectrum of this star resembles that of a star of the fifth type reversed upon a continuous spectrum.</p> <p>11 54.8. The spectrum of this star resembles that of Z. C. 10^b 2112.</p> | <p><i>h. m.</i>
13 26.4. Position for 1875, R. A. = 13^h 24^m 41^s.8, Dec. = - 65° 19' 50".</p> <p>15 7.1. Position for 1875, R. A. = 15^h 5^m 3^s.2, Dec. = - 59° 22' 27".</p> <p>15 46.7. Spectrum continuous. $H\beta$, $H\gamma$, and $H\delta$, bright.</p> <p>17 3.5. Position for 1875, R. A. = 17^h 1^m 26^s.0, Dec. = - 55° 14' 20".</p> <p>17 14.6. The spectrum of this star resembles that of Z. C. 10^b 2112.</p> <p>17 33.5. Position for 1875, R. A. = 17^h 31^m 15^s.6, Dec. = - 57° 50' 57". The spectrum of this star resembles that of Z. C. 10^b 2112. It also resembles that of the adjacent star A. G. C. 23935, announced as a variable in Circular No. 24.</p> <p>17 38.1. Position for 1875, R. A. = 17^h 36^m 18^s.8, Dec. = 44° 31' 4".</p> <p>17 52.8. Position for 1875, R. A. = 17^h 50^m 41^s.5, Dec. = - 56° 16' 23".</p> <p>18 5.9. The spectrum of this star resembles that of Z. C. 10^b 2112.</p> <p>18 11.1. Position for 1875, R. A. = 18^h 9^m 12^s.9, Dec. = - 46° 2' 29".</p> <p>18 27.9. Position for 1855, R. A. = 18^h 25^m 3^s.1, Dec. = - 22° 44' 44".</p> |
|---|---|

The bright line $H\beta$ in the spectra of η Centauri, A. G. C. 17739, and κ Apodis, A. G. C. 20878, has been found to be variable, by Miss A. J. Cannon. The star Z. C. 18^b 1935, announced as of the fourth type in Circular No. 32, appears to have a spectrum of the same class as Z. C. 10^b 2112, described above.

EDWARD C. PICKERING.

JULY 6, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 61.

OPPOSITION OF EROS (433) IN 1903.

The planet Eros is now so near the Sun, that further observations of its light have become impossible. At the same time, sufficient material has not been accumulated since the discovery of its variation in light, to determine satisfactorily the laws governing it. It is, therefore, a matter of no little interest to learn when further observations can be obtained. Since three times the tropical period is about seven years, the favorable conditions of 1893 and 1900, will not recur until 1907. The next opposition will occur in 1903, under conditions similar to those in 1896. The planet was then so far south that had its existence been known at that time it could not have been observed readily, either in the United States or Europe. It, accordingly, becomes important to trace the path for the next two or three years. The positions have been computed by Miss Anna Winlock by means of the elements given by Millosevich (Astron. Nach. 155, 25) for the following dates with the results given below:—

TABLE I.
COMPUTED POSITIONS.

J. D.	Date, 1901-02.			R. A. 1900.	Dec. 1900.	log r.	log Δ.	J. D.	Date, 1902-03.			R. A. 1900.	Dec. 1900.	log r.	log Δ.
	y.	m.	d.	h.	m.	°	'		y.	m.	d.	h.	m.	°	'
5501	01	4	26	8	39.1	— 0	38	0.1025	9.8251	6040	02	10	17	9	56.7
5506	"	5	1	8	54.7	— 1	41	0.1076	9.8447	6080	"	11	27	12	8.3
5516	"	"	11	9	25.2	— 3	44	0.1179	9.8841	6160	03	2	14	16	3.5
5556	"	6	20	11	20.4	—11	23	0.1587	0.0340	6200	"	3	26	17	38.2
5596	"	7	30	13	7.4	—18	11	0.1939	0.1657	6240	"	5	5	18	4.9
5636	"	9	8	14	51.6	—23	24	0.2208	0.2732	6250	"	"	15	17	53.4
5676	"	10	18	16	36.6	—25	59	0.2391	0.3543	6260	"	"	25	17	36.0
5716	"	11	27	18	21.1	—25	2	0.2491	0.4085	6280	"	6	14	16	52.7
5745	"	12	26	19	34.3	—21	59	0.2512	0.4310	6300	"	7	4	16	24.6
5800	02	2	19	21	44.4	—11	21	0.2435	0.4364	6310	"	"	14	16	20.0
5840	"	3	31	23	13.7	— 0	44	0.2281	0.4116	6320	"	"	24	16	20.9
5880	"	5	10	0	45.7	+11	10	0.2041	0.3658	6360	"	9	2	17	1.2
5920	"	6	19	2	31.4	+22	49	0.1717	0.3034	6400	"	10	12	18	12.4
5960	"	7	29	4	44.7	+30	58	0.1323	0.2360	6440	"	11	21	19	36.6
6000	"	9	7	7	24.1	+29	56	0.0914	0.1653						

The intervals between these dates are so large, in some cases, that interpolation by the usual method is impossible. Moreover, only approximate positions are needed, since for a large portion of the time Eros will probably be too faint to be observed. To show the general form of its path, so as to prepare plans for observing it, the approximate ephemeris, given in Table II, has been determined graphically for every ten days. After trying various methods, curves were drawn, with Julian Days as abscissas, and ordinates equal to the four tabular quantities given in Table I. For each of these curves, the ordinate for every ten days was next read. First differences were taken, and points again plotted, with these differences, on a much larger scale, as ordinates. A smooth curve was drawn through these points, and the ordinates again read. Regarding these last readings as first differences, the original ordinates were approximately reproduced by successive summations. We thus obtain an ephemeris in which the accidental errors are very small, but which may differ systematically from the computed values, if the curve of first differences is drawn too high or too low. This systematic error was corrected by plotting points with abscissas equal to the Julian Day, and ordinates equal to the difference between the computed values and those given by the approximate ephemeris. These points should lie on a smooth curve, whose ordinates serve to correct the approximate ephemeris. In this way, we obtain an ephemeris, passing through all the computed points, in which the accidental errors are small. Systematic errors may enter between the computed points, since these portions of the curve are necessarily indeterminate. The results are given in Table II, the last column giving the magnitude, uncorrected for phase and assuming, as in Circular No. 49, that the magnitude at distance unity is 11.39.

TABLE II.

APPROXIMATE EPHEMERIS OF EROS.

J. D.	Date, 1901.			R. A. 1900.	Dec. 1900.	log <i>r</i> .	log Δ .	Magn.	J. D.	Date, 1901.			R. A. 1900.	Dec. 1900.	log <i>r</i> .	log Δ .	Magn.		
	<i>y.</i>	<i>m.</i>	<i>d.</i>	<i>h.</i>	<i>m.</i>	$^{\circ}$				<i>y.</i>	<i>m.</i>	<i>d.</i>	<i>h.</i>	<i>m.</i>	$^{\circ}$				
5500	01	4	25	8	36	- 0.4	0.102	9.821	11.01	5590	01	7	24	12	52	-17.2	0.189	0.146	13.07
5510	"	5	5	9	7	- 2.5	0.112	9.860	11.25	5600	"	8	3	13	18	-18.8	0.197	0.176	13.25
5520	"	5	15	9	37	- 4.5	0.122	9.899	11.49	5610	"	8	13	13	44	-20.3	0.204	0.204	13.43
5530	"	5	25	10	6	- 6.6	0.131	9.937	11.73	5620	"	8	23	14	10	-21.6	0.211	0.231	13.60
5540	"	6	4	10	35	- 8.5	0.141	9.974	11.97	5630	"	9	2	14	36	-22.7	0.217	0.257	13.76
5550	"	6	14	11	3	-10.3	0.151	0.011	12.20	5640	"	9	12	15	2	-23.7	0.223	0.281	13.91
5560	"	6	24	11	31	-12.1	0.162	0.047	12.43	5650	"	9	22	15	28	-24.5	0.228	0.303	14.05
5570	"	7	4	11	58	-13.8	0.172	0.081	12.65	5660	"	10	2	15	54	-25.1	0.233	0.323	14.17
5580	"	7	14	12	25	-15.5	0.181	0.114	12.87	5670	"	10	12	16	20	-25.6	0.237	0.342	14.29

CIRCULAR NO. 61.

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J. D.	Date, 1901-02.	R. A. 1900.	Dec. 1900.	log r.	log Δ.	Magn.	J. D.	Date, 1902-03.	R. A. 1900.	Dec. 1900.	log r.	log Δ.	Magn.
	y. m. d.	h. m.	°					y. m. d.	h. m.	°			
5680	01 10 22	16 47	-25.9	0.240	0.360	14.39	6070	02 11 17	11 37	+ 2.3	0.054	0.087	12.09
5690	" 11 1	17 13	-26.1	0.243	0.376	14.49	6080	" 11 27	12 8	- 2.8	0.056	0.080	12.07
5700	" 11 11	17 40	-25.9	0.245	0.390	14.57	6090	" 12 6	12 39	- 7.9	0.060	0.074	12.06
5710	" 11 21	18 6	-25.6	0.247	0.402	14.63	6100	" 12 16	13 9	-12.9	0.066	0.068	12.06
5720	" 12 1	18 32	-25.0	0.249	0.413	14.70	6110	" 12 26	13 39	-17.5	0.073	0.062	12.07
5730	" 12 11	18 58	-24.1	0.250	0.422	14.75	6120	03 1 5	14 9	-21.7	0.081	0.056	12.07
5740	" 12 21	19 24	-22.9	0.250	0.429	14.79	6130	" 1 15	14 38	-25.5	0.090	0.050	12.09
5750	" 12 31	19 49	-21.5	0.250	0.434	14.81	6140	" 1 25	15 7	-28.8	0.099	0.043	12.10
5760	02 1 10	20 14	-19.8	0.249	0.437	14.82	6150	" 2 4	15 35	-31.5	0.109	0.035	12.11
5770	" 1 20	20 38	-18.0	0.248	0.439	14.83	6160	" 2 14	16 3	-34.0	0.119	0.025	12.11
5780	" 1 30	21 2	-16.0	0.247	0.439	14.82	6170	" 2 24	16 30	-36.1	0.129	0.013	12.11
5790	" 2 9	21 23	-13.7	0.246	0.438	14.81	6180	" 3 6	16 55	-37.9	0.140	9.997	12.07
5800	" 2 19	21 44	-11.3	0.244	0.436	14.79	6190	" 3 16	17 18	-39.4	0.150	9.977	12.03
5810	" 2 29	22 16	- 8.8	0.241	0.433	14.76	6200	" 3 26	17 38	-40.7	0.160	9.954	11.96
5820	" 3 11	22 28	- 6.2	0.238	0.427	14.71	6210	" 4 5	17 54	-42.0	0.169	9.929	11.88
5830	" 3 21	22 51	- 3.5	0.233	0.420	14.65	6220	" 4 15	18 5	-43.1	0.178	9.903	11.79
5840	" 3 31	23 14	- 0.7	0.228	0.412	14.59	6230	" 4 25	18 9	-44.0	0.186	9.878	11.71
5850	" 4 10	23 37	+ 2.2	0.224	0.402	14.52	6240	" 5 5	18 5	-44.6	0.194	9.854	11.63
5860	" 4 20	0 0	+ 5.2	0.219	0.391	14.44	6250	" 5 15	17 54	-45.0	0.202	9.833	11.57
5870	" 4 30	0 23	+ 8.2	0.213	0.379	14.35	6260	" 5 25	17 36	-44.7	0.209	9.820	11.54
5880	" 5 10	0 47	+11.2	0.204	0.366	14.25	6270	" 6 4	17 14	-43.5	0.215	9.817	11.55
5890	" 5 20	1 11	+14.1	0.197	0.351	14.13	6280	" 6 14	16 53	-41.4	0.221	9.828	11.63
5900	" 5 30	1 36	+17.0	0.190	0.335	14.01	6290	" 6 24	16 36	-38.8	0.226	9.850	11.77
5910	" 6 9	2 3	+20.0	0.181	0.319	13.89	6300	" 7 4	16 25	-35.9	0.231	9.883	11.96
5920	" 6 19	2 31	+22.8	0.172	0.303	13.77	6310	" 7 14	16 20	-33.3	0.236	9.922	12.18
5930	" 6 29	3 3	+25.4	0.162	0.287	13.63	6320	" 7 24	16 21	-31.1	0.240	9.964	12.41
5940	" 7 9	3 36	+27.7	0.152	0.270	13.50	6330	" 8 3	16 27	-29.4	0.243	0.006	12.63
5950	" 7 19	4 10	+29.6	0.142	0.253	13.37	6340	" 8 13	16 36	-27.9	0.245	0.047	12.85
5960	" 7 29	4 45	+31.0	0.132	0.236	13.23	6350	" 8 23	16 47	-26.7	0.247	0.087	13.06
5970	" 8 8	5 23	+31.7	0.121	0.218	13.09	6360	" 9 2	17 1	-25.9	0.249	0.125	13.26
5980	" 8 18	6 4	+31.8	0.111	0.199	12.94	6370	" 9 12	17 17	-25.4	0.250	0.159	13.43
5990	" 8 28	6 45	+31.2	0.101	0.181	12.80	6380	" 9 22	17 34	-24.7	0.251	0.191	13.60
6000	" 9 7	7 24	+29.9	0.091	0.165	12.67	6390	" 10 2	17 52	-33.9	0.251	0.221	13.75
6010	" 9 17	8 3	+27.8	0.082	0.151	12.55	6400	" 10 12	18 12	-23.0	0.251	0.248	13.89
6020	" 9 27	8 42	+25.0	0.074	0.138	12.45	6410	" 10 22	18 32	-22.1	0.250	0.272	14.01
6030	" 10 7	9 20	+21.3	0.067	0.126	12.35	6420	" 11 1	18 53	-21.1	0.249	0.294	14.10
6040	" 10 17	9 57	+17.0	0.061	0.115	12.27	6430	" 11 11	19 15	-20.1	0.247	0.313	14.19
6050	" 10 27	10 32	+12.3	0.057	0.105	12.20	6440	" 11 21	19 37	-19.0	0.244	0.329	14.25
6060	" 11 7	11 5	+ 7.3	0.055	0.095	12.14							

It will be noticed that the earliest favorable time for observation is in the Spring of 1903. It is expected that Professor Bailey will make an extensive series of photometric measures of Eros during this period, at the Arequipa Station.

EDWARD C. PICKERING.

August 10, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 62.

SPECTRUM OF LIGHTNING.

PHOTOGRAPHS of the spectrum of lightning were obtained on July 18 and 21, 1901, by Mr. J. H. Freese, under the direction of Mr. Edward S. King. The 8-inch Draper Telescope was used with an objective prism. The telescope was directed to the portion of the sky in which the lightning was particularly bright, and when the observer thought that he had obtained an image, the plate was changed. Even then many of the plates were badly fogged. A number of photographs were taken in this way, and showed the curious fact that the spectrum of lightning is not always the same. One flash, on July 18, showed three bright bands, while another taken on the same evening showed ten bright lines, and closely resembled one taken on July 21. The latter is shown in Figure 1. To increase the contrast of the original negative, a double contact print was made from it with slow plates, and is reproduced in the figure on the original scale.

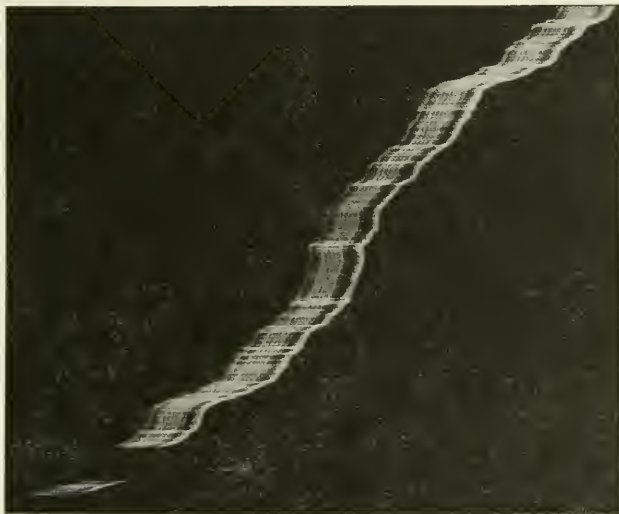


FIGURE 1.

The brighter portion of a second flash, clearly seen in the original negative, also appears in the print. Measures, each consisting of three settings, were made of three portions of the principal spectrum, and the means of the results are given in Table I. The original negative was an isochromatic plate. The successive columns give the hydrogen lines with which certain of the lines are assumed to be identical, the mean wave length and intensity of the lines in the spectrum of lightning, and the wave length and intensity of the principal lines in the spectrum of Nova Persei, No. 2, on March 23, 1901.

TABLE I.
SPECTRA OF LIGHTNING AND NOVA PERSEI.

H _{yd.}	W. L.	Int.	W. L.	Int.	H _{yd.}	W. L.	Int.	W. L.	Int.
H _η	....	..	3836	4	H _γ	4341	5	4341	10
H _ζ	3881	10	3889	5		4441	?	4468	4
H _ε	3956	2				4519	1	4573	3
	3998	3	3970	7		4643	8	4646	6
	4046	2	4030	2		4754	1	....	..
H _δ	4102	8	4102	8	H _β	4861	5	4862	10
	4147	4	4149	1		4940	?	4925	1
	4187	?	....	..		5022	2	5015	3
	4222	5	R	2		5173	1	5171	3
	4263	1	....	..		5595	30	R	20

The first line in the spectrum of lightning is a broad, bright band, extending from wave length 3830 to 3930, and is perhaps identical with the nebular line 3875. The line 4222 appears as a broad band in the Nova. The last band is very broad or perhaps a continuous spectrum extending in both objects from about wave length 5300 to 6000. The lines in the two spectra appear to resemble each other closely both in position and in intensity. On September 15, 1901, a photograph was obtained with the 11-inch Draper Telescope, showing nearly thirty bright lines. Some of these show a curious doubling, the separation varying in different portions of the flash. Apparently, this is due to another flash, in whose spectrum only a portion of the lines appear.

EDWARD C. PICKERING.

NOVEMBER 16, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 63.

AN ASTEROID ORBIT OF GREAT ECCENTRICITY.

From an examination of a plate taken on August 14, 1901, with the Bruce Telescope, Dr. Stewart found an asteroid having the great southern declination, -62° . As no known asteroid was so far south at that time, a series of photographs was taken, from which, and from one previous photograph, the approximate positions given in Table I have been derived.

TABLE I.

OBSERVED POSITIONS.

Date, 1901.	G. M. T.	R. A., 1900.	Dec., 1900.
	<i>h. m.</i>	<i>h. m.</i>	$^{\circ}$ $'$
Aug. 5	16 10	19 33.7	-62 36.1
" 14	15 12	19 27.4	-61 30.0
" 15	16 15	19 27.2	-61 20.2
" 17	14 25	19 27.1	-61 0.5
" 20	14 33	19 27.25	-60 26.7
" 23	14 47	19 28.2	-59 48.5
Sept. 2	12 54	19 35.1	-57 17.5
" 11	16 13	19 46.3	-54 29.4
" 18	13 59	19 57.1	-52 6.7
" 30	12 54	20 19.2	-47 34.0
" 30	13 46	20 19.25	-47 33.2
Oct. 1	14 41	20 21.3	-47 8.1
" 2	15 09	20 23.4	-46 43.7
Nov. 13	12 43	21 52.5	-28 14.

A circular orbit was first computed by Miss Anna Winlock. This gave the surprising result that the heliocentric diurnal motion exceeded $2200''$, corresponding to a distance from the Sun less than that of any known asteroid. As Professor Newcomb was spending a few days in Boston, he courteously undertook, with the assistance of Miss Winlock, to determine elliptical elements for this object. The results are given on the next page:—

ELEMENTS.

Epoch 1901, October 2.627, G. M. T.

$$\begin{array}{lcl}
 M = 358^{\circ} 30' & & \phi = 22^{\circ} 8' \\
 \omega = 301^{\circ} 19' & & \mu = 860'' \\
 \Omega = 35^{\circ} 48' & \left. \vphantom{\begin{array}{l} M \\ \omega \\ \Omega \\ i \end{array}} \right\} 1900.0 & \log a = 0.4103 \\
 i = 18^{\circ} 38' & & \text{Period} = 4.13
 \end{array}$$

The uncertainty of the elements, ω and Ω , may be estimated at $\pm 1^{\circ}$.

From these elements it appears that the great peculiarity of this orbit is the ellipticity, which exceeds that of any known asteroid. The only other asteroids for which ϕ exceeds 20° , are Eva (164) for which it is $20^{\circ} 19'$, and Istria (183) for which it is $20^{\circ} 27'$.

At the time of discovery the asteroid was near perihelion, and therefore was moving very rapidly around the Sun, at a distance of about 1.6. An approximate ephemeris for Greenwich Midnight is given in Table II, which shows that the asteroid is moving rapidly north, and is now within reach of the telescopes in Europe and the United States.

TABLE II.

APPROXIMATE EPHEMERIS.

J. D.	Date, 1901-02.	R. A. 1900.0.	Dec. 1900.0.	$\log r$.	$\log \Delta$
		<i>h.</i> <i>m.</i>	<i>^{\circ}</i> <i>'</i>		
5560	June 24.5	20 8.1	-56 33	0.2598	9.9613
5580	July 14.5	19 54.4	-61 28	0.2434	9.9273
5600	Aug. 3.5	19 31.6	-62 41	0.2288	9.9208
5620	" 23.5	19 26.2	-59 52	0.2171	9.9360
5640	Sept. 12.5	19 46.2	-54 14	0.2090	9.9660
5660	Oct. 2.5	20 22.1	-46 49	0.2052	0.0064
5680	" 22.5	21 4.2	-38 16	0.2060	0.0549
5700	Nov. 11.5	21 47.5	-29 14	0.2114	0.1095
5720	Dec. 1.5	22 30.0	-20 15	0.2209	0.1674
5740	" 21.5	23 11.3	-11 42	0.2338	0.2258
5760	Jan. 10.5	23 51.8	- 3 47	0.2491	0.2819
5780	" 30.5	0 31.9	+ 3 26	0.2661	0.3339

The position for November 13, given above, was obtained by cablegram from Arequipa, and indicates that the errors of the ephemeris on that date, in right ascension and declination, are $-0^m.7$ and $-4'$, respectively.

EDWARD C. PICKERING.

NOVEMBER 19, 1901.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 64.

EARLY OBSERVATIONS OF ALGOL STARS.

ONE of the most important uses of the collection of photographs at Cambridge is to determine early dates of minima of stars of the Algol type. Nearly all of the early photographs were taken with the 8-inch Draper Telescope. The number has been greatly increased during the last three years by supplementing its work with anastigmat lenses. In the *Astron. Nach.* 156, 313, Mr. Williams announces that the star 78.1901, R. A. = $20^h 18^m 4^s.0$, Dec. = $+42^\circ 46'.4$ (1855), is a star of the Algol type. One hundred and seventy-seven photographs of this region were contained in the Harvard collection, the first being on September 19, 1885. On ten of these the star was distinctly fainter than its normal brightness. Measures with the 12-inch Meridian Photometer gave the maximum magnitude of this star 10.47. Assuming this value, a light curve, whose coördinates are given in Table I, was determined by Professor Wendell from observations with the 15-inch telescope.

The various determinations of the minima are enumerated in Table II. The year, month, and day are given in the first column, the Greenwich Mean Time in the second, the Julian Day and fraction in the third, and the photographic magnitude in the fourth. The fifth column gives the time from minimum, indicated by the magnitude according to the light curve, assuming that the normal photographic magnitude is 10.2. On three of the plates the star was not seen, although stars of the magnitude 11.7 were visible. This indicates that the star was within 0".06 of minimum. The last four lines relate to visual observations, three by Mr. Williams and the last one by Professor Wendell. The letter m is entered in the fourth column, and the value in the fifth is of course zero. The adopted formula for the times of minima is $2,410,000.20 + 3.45083 E$, which agrees closely with that given by Mr. Williams. The value of E is given in the sixth column, and the deviation O-C in the seventh. These deviations must be corrected by the values in the fifth

TABLE I.
LIGHT CURVE.

Ph.	Dec.	Inc.
<i>d</i>		
0.20	10.47	10.47
0.18	10.55	10.50
0.16	10.67	10.57
0.14	10.81	10.75
0.12	11.07	11.03
0.10	11.15	11.11
0.08	11.45	11.38
0.06	11.80	11.75
0.04	12.22	12.16
0.02	12.76	12.64
0.00	13.05	13.05

column, although they are sometimes thus increased. In the first line the correction may have any value from $+0^d.06$ to $-0^d.06$, but even the latter leaves the deviation $+0^d.009$. In the second line the magnitude 10.83 shows that the time of minimum must have preceded or followed the time of observation by $0^d.121$.

It is by no means certain that the best value of the period, $3^d.45083 = 3^d 10^h 49^m 12^s$, has been found. A change of one or two seconds would, however, increase the residuals perceptibly. It is curious, and perhaps suspicious, that the correction has always been taken with the negative sign, that is, that the star when photographed was in each of the ten cases increasing in light. One result, that on J. D. 4193, seems entirely wrong. The minimum apparently took place half a day too late. Some of the large residuals occur when the star is bright, or when it is changing slowly. We should expect that they would be the most uncertain. It is probable that more accurate results can be obtained when the photographic light curve is better known, and also by correcting for aberration.

TABLE II.
OBSERVED MINIMA OF 78.1901.

Y. M. D.			G. M. T.		J. D.	Magn.	Curve.	E.	Unc.	Corr.
			$h.$	$m.$	$d.$		$d.$		$d.$	$d.$
1890	5	16	19	56	1504.831	<11.7	$\pm .06$	436	$+ .069$	$+ .009$
1891	1	13	10	50	1746.451	10.83	$-.121$	506	$+ .131$	$+ .010$
1892	9	18	14	07	2360.588	<11.7	$\pm .06$	684	$+ .020$	.000
1893	7	29	18	04	2674.753	10.67	$-.143$	775	$+ .160$	$+ .017$
1894	9	23	14	03	3095.585	<11.3	$\pm .08$	897	$-.010$	.000
1895	8	10	14	52	3416.619	10.98	$-.107$	990	$+ .097$	$-.010$
1896	8	20	16	32	3792.689	<11.7	$\pm .06$	1099	$+ .027$	.000
1897	9	25	14	46	4193.615	10.86	$-.120$	1215	$+ .657$	$+ .537$
1898	1	13	10	43	4303.447	11.62	$-.062$	1247	$+ .062$	.000
1899	10	3	13	43	4931.572	10.52	$-.162$	1429	$+ .136$	$-.026$
1901	8	24	14	27	5621.602	m	.00	1629	.000	.000
"	9	7	9	43	5635.405	m	.00	1633	.000	.000
"	"	14	7	29	5642.312	m	.00	1635	$+ .005$	$+ .005$
"	11	1	14	47	5690.617	m	.00	1649	$-.002$	$-.002$

In the *Astron. Nach.* 157, 79, Dr. Schwab announced that the star $+19^{\circ} 39'75$, 93.1901. R. A. = $19^h 14^m 26^s$, Dec. = $+19^{\circ} 25'.4$ (1900), was a variable of the Algol type. From the *Harvard Annals*, Vols. XXIV and XLV, it appears that the photometric magnitude of this star when at full brightness is 6.50, the range in the measures on four nights being less than a tenth of a magnitude. An examination of the Harvard photographs showed that we had 155 images in which its brightness was

nearly normal, and 13 in which it was near minimum. For the observations near minimum, Table III gives in successive columns the year, month, and day, the Greenwich Mean Time, the Julian Day and fraction, the approximate magnitude, the assumed value of E , and the uncorrected residual found by subtracting the time computed by the formula, $2,410,011.6 + 17 E$.

TABLE III.
OBSERVED MINIMA OF 93.1901

Y. M. D.			G. M. T.		J. D.	Magn.	E .	Unc.
			<i>h.</i>	<i>m.</i>	<i>d.</i>			<i>d.</i>
1887	8	3	15	35	0487.649	7.06	28	+0.05
1890	11	5	10	48	1677.450	9.15	98	-0.15
1891	7	13	16	28	1927.686	8.68	113	-4.91
1893	8	4	15	2	2680.626	7.06	157	+0.03
"	"	"	15	14	2680.635	7.06	"	+0.04
1894	10	15	12	8	3117.506	7.35	183	-5.09
1895	8	22	13	22	3428.557	8.74	201	-0.04
"	"	"	14	25	3428.601	8.11	"	0.00
"	9	8	14	22	3445.599	8.40	202	0.00
1897	9	24	13	31	4192.563	7.06	246	-1.04
1900	5	22	19	33	5162.815	7.80	303	+0.22
1901	5	12	19	4	5517.794	8.74	324	-1.81
1901	7	12	17	13	5578.713	9.15	327	+8.11
"	"	"	17	28	5578.728	9.11	"	+8.13
"	10	8	13	14	5666.551	8.68	333	-6.05
"	11	1	6	30	5690.27	m	334	+0.67
"	"	28	12		5717.50	m?	336	-6.10
1902	1	4	12		5754.5	m?	338	-3.10

The photograph on J. D. 3428 is especially valuable. The spectrum, which is of the first type like other Algol stars, trailed over the plate, and showed that the star was at first of about the ninth magnitude, after about half an hour suddenly becoming brighter until it attained the eighth magnitude at the end of the exposure. Two lines have, therefore, been given to this plate. When the law of variation becomes known this will probably give an accurate value of the time of minimum. The last line but two represents the observation of Dr. Schwab, the last line but one that of Professor Wendell. On this last date, the star had apparently nearly recovered its full brightness, the range of the observations not exceeding two tenths of a magnitude. The last line represents a somewhat uncertain observation by Mr. White when the star was near the horizon. The range in light appears to be greater than that of any other Algol star. The period, 17 days, given by

Dr. Schwab, is longer than that of any other Algol variable, and does not satisfy the observations. No subdivision, or other value of the period, appears to give better results. By a slight change in the period, and by applying a correction for the light curve and for aberration, about half of the residuals in the last column of Table III could be reduced nearly to zero. The others are so large, amounting to several days, that their careful study becomes a matter of very great importance. If these discordances are due to a third body this star will become one of the most interesting in the sky. Evidently it should be carefully watched. This has been done at Cambridge ever since its variability was announced. On two dates, November 18 and December 22, 1901, when minima were expected, according to the formula of Dr. Schwab, clouds prevented observations, and on a third day, December 5, 1901, no diminution in light was perceptible. During the coming year it is proposed to look at it early and late on each clear evening at Cambridge and Arequipa. The value of this work would be greatly increased if observers in other longitudes would cooperate. A continuous watch might thus be kept upon it, and no minima missed. The observations needed are very simple. The star when at full brightness is easily seen with an opera glass, and it is only necessary to select two adjacent stars, one a little brighter, the other a little fainter, as $+19^{\circ} 3956$ and $+18^{\circ} 4043$, and see each night if the brightness is normal. Any observations when the star is faint will be very valuable. If the observer is not accustomed to the method of Argelander, it will only be necessary to name one or two stars which are a little brighter and others a little fainter at a given hour and minute. These observations should be repeated two or three times an hour to detect changes. The stars may be identified by a sketch of the region, if desired. The value will be greatly increased if any kind of photograph can be taken, attaching a hand camera to an equatorial or even allowing the stars to trail through the field. The detailed observations should be forwarded at once by mail, and if possible the time of minimum cabled. For instance, "Observatory, Boston, Schwab twenty-first sixteen, Smith," would be understood to mean that Mr. Smith found Schwab's variable at minimum on the twenty-first of the current, or preceding, month at sixteen hours after Greenwich Mean Noon. The message sent from here, "Schwab, May twenty-first," would indicate that a minimum was predicted for that date, and that observations on that evening were greatly desired. It is hoped that by the aid of astronomers in Asia and Australia it will be possible to follow the star continuously during the present year, so that no minima will be missed, or if only during a limited period, as the month of July, 1902, when the star is in opposition to the Sun.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 65.

A NEW ALGOL VARIABLE. $+43^{\circ} 4101$.

A STRIKING illustration of the value of the library of glass photographs collected at this Observatory during the past seventeen years has been shown within the last few days. Comet a 1902 was discovered by Dr. Brooks on April 14, and it was found that a photograph had been taken here on April 3 with the 8-inch Draper Telescope, approximately in the direction from which the comet came. An examination of this plate was accordingly made by Mrs. Fleming, superposing it upon another plate of the same region taken with the same instrument on March 7, 1900. No trace of the comet was found, and in fact the elements now indicate that it was a little beyond the region covered by the photograph. One star, however, in the constellation Lacerta, according to Heis, but in Cygnus according to the Uranometria Nova, appeared faint on the early plate and bright on that taken later. A further examination showed that this object was the north preceding component of $+43^{\circ} 4101$. Its position for 1900 is R. A. = $21^h 55^m.2$, Dec. = $+43^{\circ} 52'$. The difference in right ascension of the two components is about $2^s.0$, the difference in declination, $0'.3$. A further examination showed that the star was generally bright and constant in light, so that it must be a variable of the Algol type. It is not very distant from the remarkable variable star SS Cygni which precedes it $16''$, and is $44'$ south. This last star was discovered at this Observatory in 1896 and is ordinarily faint, becoming suddenly bright at intervals which appear to be irregular. Only one other star, U Geminorum, is known to undergo similar changes. The star, SS Cygni, has been carefully studied here, several hundred photographs having been taken of it. It has also been observed visually on several hundred nights both here and elsewhere, but as yet the law regulating its outbursts of light has not been discovered. Again the advantage of the photographic method is indicated, since each plate taken for SS Cygni can be used for studying the new variable, or any others that may be discovered in this part of the sky, as well as if taken for each alone, while of course the visual observations of SS Cygni can be used for no

other star. The total number of plates showing the new variable at full brightness is 388, of which 1 was taken in 1889, 10 in 1890, 12 in 1891, 8 in 1892, 9 in 1893, 3 in 1894, 10 in 1895, 37 in 1896, 184 in 1897, 30 in 1898, 37 in 1899, 28 in 1900, 7 in 1901, and 12 in 1902. Besides these, the star appears on 54 photographs taken with the 2.5 inch Anastigmat, but they have not been included in the present discussion, since the proximity of the other component in some cases renders it difficult to decide whether the variable is at its full brightness, or not.

Besides these plates, 19 were found on which the variable, which ordinarily has the magnitude 8.9, was of the magnitude 9.3 or fainter. They are enumerated, together with six others taken later, in Table I, which gives in the first three columns the year, month, and day, the Greenwich Mean Time of the middle of the exposure in hours and minutes, and the Julian Day and thousandths. The fourth column gives the photographic magnitude, and the fifth, the correction to the minimum corresponding to this magnitude. A positive sign denotes that the photograph was taken before minimum, a negative sign, after. When the star was not seen, the plus and minus sign is used to indicate that the correction may have any value within the limits given. Thus, the star was of the magnitude 10.5 for about $0^d.71$ before and after minimum, and accordingly any correction between $+0^d.71$ and $-0^d.71$ may be applied to the observed time of the second plate without indicating an error in the observation. All of these values are derived from the light curve found as described below. At first the period was thought to be $1^d.498$, but this was found to be an error. The true period appears to be about $31^d.304$, and the times of minimum are represented by the formula, $2,410,015.05 + 31.304 E$. The value of E , and the residual found by subtracting the computed time of minimum from the time of the photograph, are given in the sixth and seventh columns. The eighth column gives the corrected residual found by taking the algebraic sum of the fifth and seventh columns. The letter F is inserted when the variable was invisible, and the phase is less numerically than the correction given in the fifth column. In these cases, no correction to the period is indicated. The letter M is inserted when the phase is less than ± 0.45 and the variable is of the magnitude 11.4, or fainter, since it is then near minimum and is varying so slowly that an accurate correction cannot be obtained.

It will be seen from the last column of the table that all the magnitudes are nearly represented by the formula, except those derived from photographs taken on J. D. 1962, and 4431. On these dates, the star was at nearly its full brightness, and the deviations which amount to 0.4 of a magnitude are probably due to error of observation.

TABLE I.

OBSERVED MINIMA OF $+43^{\circ} 4101$.

Y.	M.	D.	G. M. T.		J. D.	Magn.	Corr.	E.	Phase.	Corr. Phase.
			<i>h.</i>	<i>m.</i>	<i>d.</i>					
1891	8	17	19	21	1962.806	9.28	-0.99	62	+6.908	-5.92
1892	10	22	13	31	2394.563	<10.5	± 0.71	76	+0.409	F
1895	9	20	15	24	3457.642	9.31	+0.98	110	-0.848	+0.13
1896	9	30	11	42	3833.487	10.52	+0.71	122	-0.651	+0.06
"	"	"	19	20	3833.806	<11.5	± 0.43	"	-0.332	F
"	10	1	13	35	3834.566	11.49	-0.43	"	+0.428	M
"	"	31	12	15	3864.510	9.64	+0.90	123	-0.932	-0.03
"	"	"	14	05	3864.587	10.02	+0.83	"	-0.855	-0.03
"	12	3	12	47	3897.533	9.85	-0.86	124	+0.787	+0.07
1897	1	2	10	51	3927.452	10.85	+0.64	125	-0.598	+0.04
"	4	6	20	59	4021.874	<11.7	0.00	128	-0.088	F
"	5	7	19	34	4052.815	11.54	+0.36	129	-0.451	-0.09
"	9	9	15	16	4177.636	10.02	-0.83	132	+0.846	+0.02
1898	1	13	11	02	4303.460	11.69	0.00	137	-0.238	M
"	5	21	20	04	4431.836	9.28	-0.99	141	+2.922	-1.93
1899	8	30	12	46	4897.532	9.28	+0.99	156	-0.942	+0.05
1900	3	7	21	43	5086.905	10.95	-0.60	162	+0.607	+0.01
"	8	9	20	13	5241.842	9.74	+0.89	167	-0.976	-0.09
1901	8	21	15	32	5618.647	<10.6	± 0.69	179	+0.181	F
1902	4	28	17	44	5868.739	11.54	+0.36	187	-0.159	M
"	"	"	18	18	5868.762	11.44	+0.46	"	-0.136	M
"	"	"	19	07	5868.797	11.44	+0.46	"	-0.101	M
"	"	"	19	37	5868.817	11.49	+0.44	"	-0.081	M
"	"	"	20	20	5868.847	11.44	+0.46	"	-0.051	M
"	"	"	20	34	5868.857	11.44	+0.46	"	-0.041	M

The form of light curve may be determined by plotting the magnitudes and phases given in the fourth and seventh columns. The star retains its full brightness for 28 days, its photographic magnitude at maximum being 8.9. About a day before the minimum it begins to diminish, attaining the magnitude 9.0 at $1^{\text{d}}.05$ before minimum, 9.5 at $0^{\text{d}}.94$, 10.0 at $0^{\text{d}}.84$, 10.5 at $0^{\text{d}}.71$, 11.0 at $0^{\text{d}}.58$, and 11.5 at $0^{\text{d}}.43$. The light remains nearly constant for more than half a day, with the minimum magnitude 11.6. The time of increase is more uncertain, but apparently is nearly the same as that of decrease. The period of this Algol star, 31.4 days, is more than three times that of any other as yet discovered, and the duration of minimum, 2 days, is double that of S Cancri, the next in length. The period of S Cancri is 9.5 days, and the duration of minimum 0.9 days. The last minimum of $+43^{\circ} 4101$

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occurred on April 28, 1902, at $21^h 33^m$ G.M.T. The predicted times of the next minima are May $30^d 4^h 51^m$, June $30^d 12^h 8^m$, July $31^d 19^h 26^m$, September $1^d 2^h 44^m$, and October $2^d 10^h 2^m$, 1902.

The anomalous variations of Schwab's variable, described in Circular No. 64, were explained by the period, 3.38 days, cabled by Professor Kreutz, and announced in our Bulletin of February 3, which also stated that the careful watch of this star, proposed in the Circular, would therefore not be necessary.

EDWARD C. PICKERING.

MAY 6, 1902.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 66.

MISCELLANEOUS RESULTS, No. 1.

THE circulars hitherto published have subserved their purpose in furnishing a more prompt publication of results, than would be secured by waiting for the issue of the volume of Annals which would contain them. Much material has, however, accumulated which might fill several circulars. To avoid the consequent delay, some of the results are given below in a briefer form.

VISIBILITY OF EROS.

A letter lately received from Professor Bailey states that Eros was photographed with the Bruce Telescope on July 8, 1902. The telescope was made to follow a star by means of an eyepiece adjoining the plate, while a motion was given to the latter equal to the computed motion of Eros. The stars accordingly leave trails having a direction and length corresponding to the motion of Eros, while the planet appears as a minute dot, the entire light being concentrated for the whole time of exposure upon a few silver particles. A second photograph confirmed this observation. So far as known, the first visual observation of Eros, since its recent conjunction with the Sun, was obtained by Professor H. A. Howe at the Denver Observatory on August 2, 1902, as announced in the Harvard Bulletin of August 5, 1902. It will be remembered that the first photograph of Eros after its conjunction in 1899 was also obtained with the Bruce Telescope on April 28, 1900, by the method described above. It was first seen on June 6, 1900, at the Denver Observatory, and later at the Arcetri Observatory on June 30, 1900. In like manner, it was followed after the opposition of 1900, until March 12, 1901, at Arcetri, until June 17, 1901, at Denver, and until September 9, 1901, at Arequipa, with the Bruce Telescope.

WILLIAMS' NEW ALGOL VARIABLE, 13.1902.

In order to identify the Algol variable, 13.1902, recently announced by Mr. A. S. Williams (A.N. 159, 309), its position was marked on several of the Draper Memorial photographs. On one of these, taken 1893, July 11^d 18^h 10^m, G. M. T.,

the star appeared fainter than normal. On Mr. Williams' scale its magnitude was about 11.3, or a little nearer in brightness to his star *d*, than to his star *b*. It is also very nearly equal in brightness to the star which follows the variable about 45° . north 6° .S. This would indicate that the time of minimum preceded or followed the time of taking the photograph by about three hours, assuming the light curve described by Mr. Williams. The formula he gives indicates for $E = -918$, a time of minimum J. D. 2,412,656.720 = 1893, July 11^{*a*} 17^{*h*} 17^{*m*}, G. M. T., omitting his last three decimal places which appear to be indeterminate.

This photograph, therefore, gives a correction to the ephemeris of $+4^h$ or -2^h . An examination of the other plates of this region would distinguish between these two values, and determine the correct one with much greater accuracy. Probably we have at least one hundred photographs of this region, although the star may be too faint to appear on a portion of them. On one tenth of the photographs the star should be below its normal brightness. A precise correction to the ephemeris can be found from each of these, if not too near maximum or minimum, when the photographic light curve has been found, as can now be readily done. Unfortunately, the pressure of other work will probably prevent the continuation of this research at present. As it is, the observation given above lengthens the period of observation from less than ten months to about nine years, and increases the accuracy with which the period can now be determined in nearly the same proportion.

EARLY OBSERVATIONS OF NOVA PERSEI, No. 2.

As the Nova is diminishing in light it becomes necessary to use comparison stars so faint that they are not contained in the Harvard Annals, Volume XLV or other photometric catalogues. A sequence has accordingly been selected which is given in Table I. The designation, is followed by the number, number of grades, difference in right ascension, and difference of declination from the Nova, taken from Hagen's Second Catalogue. The sixth column gives the photometric magnitude, found for the stars *b* to *f* from comparisons by Professor Wendell with star *a*. Constructing a curve with coördinates taken from the second and sixth columns, we have the means of converting the estimates of Hagen into magnitudes on the photometric scale. The seventh column gives the residual found by subtracting the magnitude given in the sixth column from the Hagen magnitude thus formed. Table II gives the photometric magnitude corresponding to various values of Hagen's grades. The fainter magnitudes found by interpolation are somewhat uncertain.

TABLE I.
SEQUENCE OF COMPARISON STARS.

Dec.	H.	Gr.	$\Delta\alpha$	$\Delta\delta$	Magn.	H-P.	Dec.	H.	Gr.	$\Delta\alpha$	$\Delta\delta$	Magn.	H-P.
			$s.$	$'$						$s.$	$'$		
a	20	67	-21	+4.8	9.10	+03	h	65	178	+42	+4.8	..	..
b	32	84	+43	+8.7	9.71	+19	k	66	179	+33	-4.1	..	..
c	34	92	-65	+3.4	10.57	-32	l	68	185	+34	+1.5	..	..
d	42	111	+35	+0.2	11.03	+01	m	74	199	+21	+1.6	..	..
e	46	133	-82	+6.3	11.94	-08	n	77	209	+13	+1.0	..	..
f	49	145	-24	-1.5	12.23	+03	o	80	..	-3	-0.5	..	..
g	56	161	-17	+2.4	..	..							

Table II furnishes the means of determining the limiting magnitude below which the Nova must have been before its discovery. The last photograph taken before it was found on February 21, 1902, was obtained by Mr. A. S. Williams on February 20. It is reproduced in Knowledge, XXIV, 152. All stars included in the region covered by the print, and brighter than Hagen No. 42, are shown except Nos. 29, 34, 36, 38, and 39. The absence of No. 39 is perhaps due to the proximity of No. 28. Stars of the magnitude 10.9 are therefore shown, and we may, hence, infer that the Nova was below this limit on February 20. Several defects appear on this print which cannot be distinguished from stars. The next photograph preceding this was obtained at this Observatory, and is shown in Figure 1 of Circular No. 57. This print shows all stars brighter than No. 49, except No. 39. The Nova must therefore have been fainter than the magnitude 12.0 on that date.

TABLE II.
RELATION OF HAGEN'S GRADES TO MAGNITUDES.

Grades.	Magnitudes.	Grades.	Magnitudes.	Grades.	Magnitudes.	Grades.	Magnitudes.
0	6.56	50	8.39	100	10.59	150	12.42
10	6.90	60	8.82	110	11.00	160	12.72
20	7.25	70	9.27	120	11.39	170	13.00
30	7.61	80	9.72	130	11.76	180	13.25
40	7.99	90	10.16	140	12.10	190	13.48

About a year ago, Father Zwack of the Georgetown College Observatory called my attention to a faint star which appeared on one of our early photographs so near the position of the Nova that careful measurements were required to determine whether the positions are identical or not. A measurement of several of the early plates gave the magnitudes of this object on October 26, December 2, 1890, January 20, March 11, December 10, 1891, January 25, 1893, October 11, 1894, October 17, 1897, and March 7, 1900, as 12.95, 13.37, <13.7, <13.4, <13.7, 14.06, 13.15, 13.46, and 13.36, respectively. The images of this star on the photographs taken in 1890 are somewhat uncertain, but a comparison of the photographs taken in 1893 and 1894 leaves little doubt of the variability of this object. Measurements of its position were made on the last three photographs mentioned above. Taking the position in which the Nova appeared as an origin, the values of x for this star are $-1''.6$, $+1''.2$, and $+0''.2$, those of y , $+1''.3$, $-1''.0$, and $-0''.2$, respectively. These measures are based on the positions of the stars Nos. 20, 56, 77, 78, 79, 80, and 81, determined micrometrically at the Lick Observatory.

The object announced by M. S. Blajko, A. N. 157, 193, which, according to his measures, followed the Nova $0^{\circ}.31$, south $7''$, on January 30, 1899, is doubtless identical with this object. Hagen's double star, No. 69, whose position is $40''$ distant from the Nova, does not appear on any of these photographs, although much fainter stars are shown.

We may therefore conclude that a star whose light varied from the thirteenth to the fourteenth magnitude was visible for several years within one or two seconds of arc of the Nova, the difference in position being less than the errors of measurement.

EDWARD C. PICKERING.

OCTOBER 31, 1902.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 67.

THE TOTAL LUNAR ECLIPSE OF OCTOBER 16, 1902.

A SERIES of measures was made, by Professor W. H. Pickering, of the diameter of the bright spot surrounding Linné before and after the passage of the shadow of the Earth during the total lunar eclipse of October 16, 1902. The measures were all made in a north and south direction, with the filar micrometer attached to the 15-inch Equatorial. The magnifying power used was 550 diameters. The seeing was fairly good, and nearly uniform throughout the observations, being about 5 on the standard scale of 10 (Harvard Annals, XXXII, 120). After the passage of the shadow it was slightly inferior, perhaps 4. Unfortunately, clouds stopped observations before an absolute measure of the quality of the seeing could be made.

TABLE I.
DIAMETER OF LINNÉ IN 1902.

Date.	G. M. T.		Micrometer.	Residuals.	Aver. Dev.	Uncorr.	Corr.
October 15	<i>h.</i>	<i>m.</i>					
	11	19	.371	.015, .004, .010	.010	2.44	2.69
" "	"	33	.352	.011, .017, .007	.012	2.30	2.55
" "	"	39	.370	.003, .001, .003	.002	2.43	2.68
" "	"	48	.360	.005, .002, .008	.005	2.36	2.61
" 16	13	22	.358	.012, .015, .026	.018	2.34	2.59
" "	"	32	.395	.004, .007, .011	.007	2.62	2.87
" "	"	43	.397	.005, .010, .015	.010	2.64	2.89
" "	15	12	.361	.012, .031, .019	.021	2.37	2.62
" "	"	23	.386	.010, .003, .008	.007	2.56	2.81
" "	"	35	.359	.011, .011, .000	.007	2.35	2.60
" "	16	13	.371	.001, .004, .004	.003	2.44	2.69
" "	"	26	.381	.017, .011, .005	.011	2.52	2.77
" "	"	38	.400	.012, .003, .015	.010	2.66	2.91
" "	"	50	.425	.004, .007, .010	.007	2.85	3.10
" "	"	58	.441	A	...	2.97	3.22
" "	"	59	...	Linné obscured	...	...	...
" "	19	25	...	Linné emerged	...	...	...
" "	"	31	.773	.145, .122, .022	.096	5.48	5.73
" "	"	43	.707	.028, .011, .017	.019	4.98	5.23
" "	"	56	.765	.022, .014, .035	.024	5.42	5.67
" "	20	10	.734	A	...	5.18	5.43

In Table I, the first two columns give the date and the Greenwich Mean Time. The third column gives the mean of the three differences derived from six micrometer settings. The residuals of the three differences are given in the fourth column, and their average deviation in the fifth. The last measure before Linné was obscured, and the last measure of the series, are each derived from but one difference. Since the micrometer readings were made by the method of placing both threads on the same side of the object, which has been found best for the measurement of fine and faint planetary detail (Harvard Annals, XXXII, 119), it is necessary to subtract a correction of 0.047 from the readings, to allow for the thickness of the micrometer thread. The result is then reduced to seconds of arc by multiplying by, $7''.54$, the pitch of the micrometer screw. A correction of $0''.25$ for subjective effect is then added, for the reason described in the above mentioned Volume, page 204. These results are given in the last two columns of the table. During the observations, on October 15, the Sun had been shining upon Linné 7.4 days, on October 16, from 8.5 to 8.7 days.

In comparing the results given in Table I with previous measures of Linné, made under similar circumstances,—that is to say, when the Sun had been shining upon it for 7, 8, or 9 days,—the first fact we note is that the spot has grown materially in size during the last three years. Of the nineteen measures made in 1898 and 1899, given in the following table, in only one case, that on December 15, 1899, was the diameter as large as the smallest measure included in the present series. The Sun had then been shining upon Linné only 7.1 days, so that the

TABLE II.
DIAMETER OF LINNÉ IN 1898 AND 1899.

Date, 1898.	Days.	Seeing.	Reference.	Diam.	Date, 1899.	Days.	Seeing.	Reference.	Diam.
April 6	9.3	3	Annals XXXII, 206	2.53	Dec. 15	7.1	4	Pop. Astr. VII, 58	2.71
Aug. 30	7.5	0	" "	2.52	" "	"	5	" "	2.54
" "	7.6	2	" "	2.35	" 16	8.1	6	" "	2.26
" 31	8.5	1	" "	2.19	" "	"	6.5	" "	2.01
Sept. 1	9.6	5	" "	2.20	" "	"	6.5	" "	1.98
" "	9.7	6	" "	2.51	" "	8.2	8	" "	2.11
" 29	8.2	3	" 260	2.19	" "	"	8	" "	1.97
Dec. 26	7.4	0	" "	2.37	" "	"	8	" "	1.93
" "	7.5	0	" "	1.89					
" "	7.6	2	" "	2.01					
" 27	8.6	0	" "	2.05					

latter had not had time to shrink to its minimum size, as was shown by the other measures made on the following day. The minimum, it will be remembered, comes 8.5 days after sunrise. The increased size of the spot this year would seem to imply increased activity of the crater.

In Fig. 1 the abscissas represent hours in Greenwich Mean Time, on October 16, 1902, taken from the second column of Table I. The ordinates represent seconds of arc taken from the last column. The two dotted lines indicate the times when the penumbra reached and left Linné, and the two heavy lines indicate the same thing for the umbra. It will be observed that on the approach of the latter the white spot began to grow in size, and that by the time the umbra had passed, the diameter of the spot was very materially increased. The increase of size amounted to about $2''.75$. This increase was unexpectedly large, for, after the eclipse of 1898, according to the measures made by Douglass, by three different methods (Harvard Annals, XXXII, 261), it amounted to only $0''.82$, $0''.73$, and $0''.15$. According to Mr. W. H. Pickering's measures, made during the eclipse of 1899 (Popular Astronomy, VIII, 58), the increase amounted to only $0''.14$.

Mr. Pickering remarks that in the present instance the great increase in size could not have been due to defective seeing after totality, for the effect of bad seeing on spots of this size is rather to diminish their dimensions, as shown by the measurements of artificial disks (Harvard Annals, XXXII, 136 and 142), and therefore could not produce the effect observed. "Moreover," he says, "this change in size was so conspicuous to the eye, even before I made any measures, that at first I queried whether the object could really be Linné. To satisfy myself I reidentified it by means of some small craterlets in its immediate vicinity. It is certain that at no time during the observations was the seeing as good nor as bad as it had been during some of the observations made in 1898 and 1899, when the spot was very much smaller, as shown by the second table.

"The real explanation of the unusually large change in size of the spot I believe to be that Linné was more active than heretofore, and therefore that there was more moisture about it to condense.

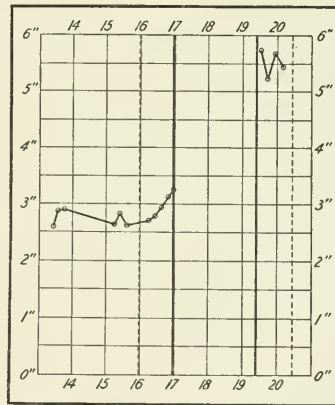


FIG. 1.

"A series of measures made on October 20, at $15^h 26^m$, or $12^d.6$ after sunrise, gave a diameter of $4''.61$. Seeing 3 on the standard scale. The seeing as judged by the image of the Moon was clearly inferior to that at any time during the night of October 16. The image of Linné was much larger than it appeared by any of the measures made before the eclipse, and much smaller than it appeared by any of the measures made after it. It therefore appears that the sudden increase of size after totality could not be due to inferior seeing.

"It also appears that on or before October 20 the spot had again begun to shrink in size, due presumably to evaporation in the intense sunlight. Four measures of the spot made in 1898, from $12^d.4$ to $13^d.7$ after sunrise, gave diameters of $3''.52$, $3''.24$, $3''.42$, and $3''.46$ (*Harvard Annals*, XXXII, 206). The measure made on October 20 of this year, $4''.61$, therefore confirms those of October 15 and 16 in showing that the spot has increased in size during the last three years.

"In future observations one should take pains to note before totality the exact position of Linné with respect to points to the east of it, so that on its reappearance from the shadow not a moment may be lost in identification. In order to secure satisfactory comparisons with the observations of past and future eclipses, it is recommended that the standard scale of seeing should be used when making these observations whenever there is an opportunity, particularly just after disappearance and before reappearance."

EDWARD C. PICKERING.

NOVEMBER 17, 1902.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 68.

TRANSPARENCY OF COMET 1902 b.

The statement is frequently made that comets are perfectly transparent, even faint stars being visible through them. The observations on which this statement is based appear to be very vague, as even if careful comparisons were made large errors might be introduced by the effect of the bright background formed by the light of the comet. The rapid motion of Comet 1902 b caused it to cover a large area and therefore rendered it easier to find a star over which it would pass. After waiting for a suitable occasion, the observations given in Table I were made by Professor O. C. Wendell with the polarizing photometer attached to the 15-inch Equatorial. On the evening of October 14, 1902, the comet passed within about 1' of the star $+21^{\circ} 3483$, photometric magnitude 7.12. This star was compared with $+21^{\circ} 3484$, magnitude 8.19. Each set of observations was the mean of sixteen settings. The Greenwich Mean Time is given in the first column, the difference in magnitude of the two stars in the second, and the deviation of this magnitude from the mean value, 1.07, in the third column. A positive sign indicates that the star $+21^{\circ} 3483$ was faint, a negative sign that it was bright. The fourth column gives the distance of the nucleus of the comet from the star. The diameter of the coma was about five or six minutes. The star was, therefore, covered by it in the first three observations. The nucleus resembled a star of about the tenth magnitude and the brightness of the coma was about that of a star of the ninth magnitude when spread over a circle one minute in diameter. The largest residual -0.05 is the last one, when the altitude of the comet was only 22° . The mean of all the residuals is ± 0.02 . It appears, therefore, that the absorption of the light by the comet, if any, is insensible, and probably does not exceed one or two hundredths of a magnitude.

TABLE I.
OBSERVATIONS.

G. M. T.		Difference.	Residuals.	Distance.
<i>h.</i>	<i>m.</i>			
13	22.5	1.06	+.01	2.0
13	33.3	1.03	+.04	1.1
13	44.7	1.10	-.03	2.0
13	57.7	1.07	.00	4.0
14	10.8	1.06	+.01	5.5
14	26.7	1.06	+.01	7.9
14	46.9	1.08	-.01	11.0
15	2.3	1.12	-.05	13.1

ASTEROIDS.

Trails of a large number of asteroids appear upon the Bruce plates, in one case no less than seven being photographed on a single plate. A list of these is in course of preparation. The positions of three of those recently found, the first by Professor Bailey, the last two by Mr. Frost, are given in Table II. The date, the Greenwich Mean Time, the right ascension for 1875, and the declination for 1875, are given in the successive columns.

TABLE II.
POSITIONS OF ASTEROIDS.

Ast.	Date.	G. M. T.	R. A. 1875.			Dec. 1875.	Ast.	Date.	G. M. T.	R. A. 1875.			Dec. 1875.
		<i>h. m.</i>	<i>h. m. s.</i>	<i>h. m. s.</i>	<i>° ' "</i>				<i>h. m.</i>	<i>h. m. s.</i>	<i>h. m. s.</i>	<i>° ' "</i>	
1	July 30, 1902	15 54	19 45 30	-22 14.0			1	Oct. 22, 1902	12 40	19 54 19	-29 43.9		
"	" 1, "	15 46	19 44 46	-22 22.9			2	Aug. 21, "	12 24	19 16 6	-29 3.9		
"	" 2, "	15 46	19 44 0	-22 31.8			"	Sept. 2, "	15 11	19 11 44	-29 16.0		
"	" 3, "	16 13	19 43 12	-22 40.8			"	" 22, "	13 24	19 13 22	-29 11.2		
"	Aug. 21, "	12 24	19 6 52	-28 59.4			"	" 30, "	13 2	19 16 59	-29 2.6		
"	Sept. 2, "	15 11	19 6 35	-29 46.4			"	Oct. 21, "	13 2	19 33 18	-28 22.6		
"	" 22, "	13 24	19 17 17	-30 21.3			3	" 21, "	13 2	19 31 48	-29 11.1		
"	" 30, "	13 2	19 24 57	-30 21.8									

No asteroids are given in the Berlin Jahrbuch for 1904 in the positions of Nos. 1 and 2. Vesta was, of course, a conspicuous object on several of the photographs.

EDWARD C. PICKERING.

JANUARY 27, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 69.

GRANT FROM THE CARNEGIE INSTITUTION.

A grant has recently been made by the Carnegie Institution, for the study of the collection of photographs at the Harvard College Observatory. For many years, two photographic doublets of similar form have been in constant use photographing the sky night after night. The aperture of each is eight inches, and the focal length about four feet. The first of these photographs was obtained with the Bache Telescope in 1885, and since 1889 this instrument has been mounted in Peru, first near Chosica and later at the Arequipa Station of this Observatory, and employed mainly in the study of the southern stars. The 8-inch Draper Telescope has, in the same way, been mounted in Cambridge, and used on the northern stars since 1889. About 30,000 eight by ten inch photographs, each covering a region ten degrees square, have been obtained with each of these telescopes. Photographic charts have been made with these instruments, covering the entire sky on from one hundred to two hundred nights, and showing all stars brighter than about the twelfth magnitude, besides many that are fainter. During the last four years, this work has been supplemented by taking photographs with two Anastigmat lenses having clear apertures of about one inch. Each photograph covers a region 30° square, and in general shows stars of the eleventh magnitude and brighter. The number of times the entire sky is covered has thus been greatly increased. The amount of material thus collected has required a special building for its accommodation, and the means of the Observatory have so far permitted but a small part of the astronomical facts contained on the photographs to be gathered. The Henry Draper Memorial has enabled the most important results to be derived from the numerous photographs of the spectra of the stars, and the past history of many of the objects discovered here to be studied. When any object of interest is discovered, the photographs permit its brightness and position to be determined on one hundred or more nights, during the last twelve years, and many important facts not recorded at any other observatory are thus determined. By the aid of the grant mentioned above, a corps of assistants will be organized, whose duty will be the study of the photographs as regards any objects

of special interest. This work has already been begun, and examples are given below of the study of a star suspected of proper motion, of a variable of the Algol type, of a variable of long period, and of asteroids not recently observed.

SUSPECTED PROPER MOTION OF $-1^{\circ} 3359$.

In a recent publication (*Astron. Nach.* 160, 316), M. Pidoux has called attention to the difference between the present position of the star, $-1^{\circ} 3359$, and that given in the Bonn Durchmusterung for 1855. A comparison with the position of $-1^{\circ} 3360$ showed that the position of $-1^{\circ} 3359$ apparently followed its position for 1855 by 2^s.4, and was north 1'.5. Although Professor Kreutz has pointed out that this difference does not greatly exceed the errors to be expected in the Durchmusterung, yet it seemed desirable to compare early and late photographs of this star in order to see if this was the true explanation. A comparison of two photographs taken with the 8-inch Draper Telescope on September 20, 1891, and on July 12, 1901, showed that the adjacent star, $-1^{\circ} 3364$, differed still more than $-1^{\circ} 3359$, from its position in the Durchmusterung. Accordingly, measures of the approximate positions of several of the adjacent stars were made by Mrs. Fleming with a plate ruled in squares a millimetre on a side, the positions being estimated to twentieths.

TABLE I.
OBSERVED POSITIONS.

DM. -1°	$\Delta\alpha$		$\Delta\delta$	
	α	δ	α	δ
3354	+0.2	+0.3	0.0	0.0
3355	-1.3	-1.1	0.0	0.0
3356	-1.3	-0.6	+0.3	+0.1
3357	-0.5	+0.2	+0.3	+0.1
3358	+0.3	+0.1	+0.8	+0.8
3359	+2.5	+2.1	+1.0	+0.9
3360	+0.1	+0.2	-0.6	-0.5
3361	+0.2	-0.3	0.0	+0.1
3362	+0.1	+0.2	-0.4	-0.5
3363	+0.2	0.0	0.0	-0.1
3364	+1.2	+1.6	-4.3	-4.2
3365	+1.5	+1.1	0.0	0.0

Table I gives the results of these measures, and shows how much the positions of these stars appear to have changed during the last half century. The number of the star in the Zone -1° is given in the first column, and the differences found by subtracting the right ascension in the Durchmusterung from those derived from the two plates are given in the second and third columns. The differences in declination are similarly given in the fourth and fifth columns. Positive signs therefore indicate that the star is now following and north of its position as given in the Durchmusterung. The deviations of $-1^{\circ} 3359$ and of $-1^{\circ} 3364$ are thus confirmed. In neither case, however, is there any evidence of change during the last ten years, and the deviations are doubtless due to errors in the Durchmusterung. In the case of $-1^{\circ} 3364$, the change in declination should have

amounted to a whole minute of arc, had the deviation been due to proper motion. It also appeared from superposing the two plates that none of these stars had a sensible proper motion, which would have been very conspicuous in the case of $-1^{\circ} 3359$, and $-1^{\circ} 3364$, had the deviations been due to this cause. Omitting these two stars, the average values of the observed differences in right ascension between the plates and the Durchmusterung are $\pm 0^s.06$ and $\pm 0^s.04$, and in declination, $\pm 0'.2$ and $\pm 0'.2$. The average differences in the results of the measures of the two plates are $\pm 0^s.03$ in right ascension, and $\pm 0'.1$ in declination. A star whose position for 1855 is R. A. $= 17^h 26^m 34^s.8$, Dec. $= -0^{\circ} 41'.6$, appears on both of these plates, and is omitted in the Durchmusterung, although it is brighter photographically than the stars 3354, 3357, 3359, 3361, 3363, 3364, and 3365, of Table I. This star does not appear to be variable, since on photographs taken on September 20, 1891, May 7, July 2, 1893, June 1, 1895, May 12, June 30, 1896, May 22, 1897, April 2, May 27, 1898, May 2, May 24, 1899, May 8, 1900, July 12, and October 10, 1901, it always appeared about one grade brighter than $-0^{\circ} 3321$, and three grades fainter than $-0^{\circ} 3320$. The spectrum of this star is apparently between the first and second types.

MME. CERASKI'S ALGOL VARIABLE. 20.1902.

In the *Astron. Nach.* 160, 303, the announcement is made that Mme. Ceraski of the Moscow Observatory has found that a star whose position for 1900 is

TABLE II.
OBSERVATIONS NEAR MINIMUM.

Y. M. D.	J. D.	Magn.	Y. M. D.	J. D.	Magn.	Y. M. D.	J. D.	Magn.
92 9 8	2350.644	12.68	01 12 18	5737.494	12.53	02 12 31	6115.583	12.74
" 10 6	2378.573	13.12	" 12 21	5740.430	12.53	" " "	" .587	12.83
96 11 22	3886.597	13.02	02 11 20	6073.10	<12.4	" " "	" .600	12.45
97 9 15	4183.601	12.59	" 12 28	6112.528	13.07	" " "	" .615	12.93
98 8 5	4507.576	12.64	" " "	" .578	13.22	03 1 9	6124.437	12.83
99 5 10	4785.40	<12.4	" " 31	6115.463	12.78	" " "	" .443	12.86
" 9 22	4920.572	<13.2	" " "	" .532	13.56	" " "	" .449	12.79
" " "	" .585	13.79	" " "	" .549	13.36	" " "	" .465	12.51
" 10 23	4951.610	<13.2	" " "	" .554	13.27	" " "	" .467	12.64
00 2 5	5056.485	13.27	" " "	" .565	13.07	" " 12	6127.430	12.64
" 8 25	5257.35	<12.4	" " "	" .569	13.01			

R. A. = $21^h 2^m 20^s.2$, Dec. = $+45^\circ 22' 35''$, is a variable of the Algol type. Ten photographs had been taken at Moscow of the region containing it, and from these it was concluded that its period was eighteen days, or a little less. One hundred and thirty-six of the Harvard photographs covered this region, but the faintness of this star, which is never brighter than the twelfth magnitude, enabled it to be studied on only ninety of them. On ten nights the star appeared to be faint, and on the others to be of nearly normal brightness. Since its announcement, it has been followed closely here, and found to be faint on four more nights. A list of the photographs on which it is faint is given in Table II. The successive columns give the year, month, and day, the Julian Day and fraction following Greenwich Mean Noon, and the photographic magnitude. The three dates on which Mme. Ceraski found the star fainter than normal, J. D. 4785, 5257, and 6073, and the four dates on which it has recently been found to be faint here, are also included.

No period has been found that satisfactorily represents these observations. An early publication is therefore made, to induce astronomers to watch this star.

TABLE III.
COMPARISON STARS.

Design.	X	Y	Magn.
h	- 87	-194	11.71
k	+461	-123	11.93
l	-112	- 60	12.17
m	- 62	+236	12.54
n	+ 72	+ 1	12.83
o	+ 69	- 73	13.11
p	+148	-238	13.33
q	+248	-328	13.79

The later photographs indicate minima at J. D. 6112.56, 6115.51, 6124.38, and at about 6127.3. These alone would give a period of about $2^d.96$, or perhaps $1^d.48$. These periods do not satisfy the earlier observations, and it seems difficult to satisfy them with any uniform period.

The magnitudes given in Table II depend upon the comparison stars contained in Table III. The designation, the rectangular coördinates expressed in seconds of arc, and referred to the variable as an origin, and the adopted photographic magnitude, are given in the successive columns.

The additional material relating to this star is contained in Table IV in an abridged form. The Julian Day and fraction, and the photographic magnitude, are given in the successive columns.

On two photographs, taken on J. D. 2678.817 and 6108.593, the images appear to be affected by defects, and give the magnitudes 12.10 and 11.77. They have not been included in Table IV. The mean of the other magnitudes is 12.35, and the average deviation from the mean is ± 0.06 .

TABLE IV.

OBSERVATIONS AT MAXIMUM.

J. D.	Magn.	J. D.	Magn.	J. D.	Magn.	J. D.	Magn.	J. D.	Magn.
1613.649	12.26	3405.761	12.40	4477.806	12.30	5175.728	12.26	6114.528	12.40
1964.676	12.30	3438.629	12.40	4507.576	12.36	" .746	12.30	" .553	12.36
1965.694	12.30	3439.760	12.40	4546.576	12.40	5203.825	12.15	" .600	12.40
" .711	12.46	3442.700	12.30	4580.539	12.30	5213.800	12.26	6116.472	12.15
2344.672	12.40	3450.591	12.30	4595.536	12.40	5326.515	12.30	" .557	12.30
2348.651	12.40	3751.598	12.40	4639.464	12.30	5334.566	12.36	6120.472	12.30
2353.621	12.40	3792.689	12.40	4773.838	12.36	5340.635	12.36	6123.461	12.21
2362.608	12.40	3807.685	12.40	4799.817	12.15	5352.522	12.40	6124.483	12.40
2363.582	12.40	3829.484	12.40	4850.724	12.40	5376.452	12.26	" .487	12.36
2374.556	12.30	3843.569	12.40	4910.595	12.26	5652.663	12.26	" .497	12.30
2383.577	12.40	3857.577	12.40	4912.534	12.40	5734.583	12.30	" .515	12.36
2665.801	12.40	3859.622	12.40	4913.535	12.40	5737.515	12.30	" .540	12.25
2668.759	12.37	3905.479	12.30	" .544	12.30	5928.826	12.40	" .568	12.30
2672.712	12.26	4034.863	12.36	4925.562	12.26	6107.457	12.26	6127.444	12.40
2674.744	12.46	4106.628	12.40	" .573	12.21	" .578	13.40	" .446	12.40
" .764	12.30	4150.815	12.40	4928.569	12.30	6108.446	12.46	" .460	12.40
2701.590	12.46	4154.751	12.30	" .579	12.40	6111.444	12.30	" .476	12.40
2705.617	12.36	4165.664	12.40	4931.572	12.30	" .519	12.36	" .476	12.00
2758.489	12.30	4183.601	12.40	" .579	12.30	" .602	12.26	" .493	12.10
2761.478	12.40	4207.647	12.36	4966.465	12.36	6114.453	12.46	" .511	12.40
2948.860	12.40	4221.464	12.26	4979.495	12.40	" .471	12.36	" .528	12.40
3112.569	12.36	4228.462	12.30	5049.951	12.36				

ANDERSON'S VARIABLE, 18.1902.

In the *Astron. Nach.* 160, 271, the Rev. T. D. Anderson announces that a star whose position for 1855 is R. A. = $16^h 10^m.3$, Dec. = $+38^\circ 8'$ is variable, and that its magnitudes on November 1, November 7, November 18, and November 21, 1902, were 8.5, 8.7, 9.2, and 9.3, respectively. From an examination, it appeared that eighty-four of the Harvard photographs show this star. There are also ninety-three photographs covering this region on which the star is not visible, but the presence of faint comparison stars shows that it must have been below its maximum brightness when these photographs were taken. In Table V, the year, month, and day, the Julian Day, and the photographic magnitude, are given in the successive columns. Plates taken with the Anastigmat lens are indicated by placing the Julian Day in *Italics*.

TABLE V.

Y.	M.	D.	J. D.	Magn.	Y.	M.	D.	J. D.	Magn.	Y.	M.	D.	J. D.	Magn.	Y.	M.	D.	J. D.	Magn.
90	7	18	1567	10.46	99	4	29	4774	12.34	01	2	24	5440	<11.7	02	2	10	5791	9.12
"	8	25	1605	11.80	"	5	11	4786	<11.7	"	"	27	5443	<11.7	"	3	10	5819	9.12
91	7	9	1923	<10.8	"	"	17	4792	<11.7	"	"	28	5444	11.72	"	"	23	5832	9.12
92	2	17	2146	<10.4	"	"	30	4805	10.86	"	3	6	5450	<11.8	"	"	31	5840	<9.8
"	3	4	2162	<11.1	"	6	13	4819	10.56	"	"	17	5461	<10.8	"	4	3	5843	9.93
"	5	9	2228	8.52	"	8	14	4881	9.49	"	"	21	5465	<11.7	"	"	"	5843	9.83
"	6	15	2265	9.59	"	"	16	4883	9.49	"	4	12	5487	<11.8	"	"	4	5844	9.93
"	"	22	2272	9.59	"	"	18	4885	10.08	"	"	13	5488	<10.2	"	"	24	5864	10.56
"	7	6	2286	10.56	"	9	15	4913	<10.9	"	"	26	5501	<11.7	"	5	8	5878	11.48
"	"	8	2288	10.56	00	1	31	5051	11.72	"	5	1	5506	<11.8	"	"	"	5878	<11.7
"	"	23	2303	11.32	"	2	6	5057	10.46	"	"	3	5508	<10.8	"	"	"	5878	11.62
"	11	19	2422	<10.4	"	"	18	5069	10.56	"	"	"	5508	11.62	"	"	17	5887	<11.3
93	6	19	2634	<10.2	"	"	"	5069	10.86	"	"	5	5510	<11.2	"	"	29	5899	12.34
"	"	30	2645	<11.2	"	"	27	5078	9.93	"	"	21	5526	<9.0	"	"	30	5900	<11.8
"	7	16	2661	11.72	"	3	12	5091	9.25	"	6	5	5541	9.83	"	"	31	5901	<11.4
"	"	23	2668	11.14	"	"	16	5095	9.12	"	"	11	5547	9.59	"	6	8	5909	<11.9
94	5	2	2951	9.12	"	"	17	5096	9.02	"	"	19	5555	9.44	"	"	20	5921	<11.3
"	6	13	2993	10.08	"	"	21	5100	9.15	"	"	25	5561	9.49	"	"	23	5924	<11.7
"	"	22	3002	<10.1	"	4	8	5118	9.60	"	"	"	5561	9.44	"	"	26	5927	<11.8
95	9	1	3438	9.49	"	"	9	5119	9.59	"	"	"	5561	9.12	"	"	28	5929	<11.2
"	"	13	3450	9.12	"	"	13	5123	9.49	"	"	27	5563	9.12	"	7	3	5934	<11.9
"	"	19	3456	9.12	"	"	20	5130	9.93	"	"	29	5565	9.49	"	"	"	5934	<11.1
96	2	25	3615	11.42	"	"	"	5130	9.83	"	7	14	5580	9.49	"	"	6	5937	13.02
"	4	30	3680	9.12	"	5	5	5145	10.96	"	"	20	5586	9.49	"	"	10	5941	<11.8
"	6	29	3740	11.42	"	"	11	5151	10.96	"	8	2	5599	9.93	"	"	28	5959	<11.1
"	8	10	3782	<11.8	"	6	4	5175	<9.8	"	"	4	5601	10.43	"	"	30	5961	<10.1
"	9	30	3833	<12.6	"	"	10	5181	<10.8	"	"	9	5606	9.93	"	"	31	5962	<10.8
97	3	31	4015	12.34	"	"	18	5189	<9.9	"	"	14	5611	9.07	"	8	2	5964	<11.7
"	6	18	4094	<11.7	"	"	21	5192	<11.2	"	"	21	5618	<9.9	"	"	4	5966	<10.3
"	"	25	4101	11.96	"	7	4	5205	<10.4	"	"	28	5625	11.42	"	"	9	5971	<10.4
"	"	26	4102	11.86	"	"	18	5219	<9.8	"	9	4	5632	<9.8	"	"	16	5978	<11.3
"	8	13	4150	9.93	"	"	"	5219	<9.8	"	"	5	5633	<9.8	"	"	28	5990	<11.1
"	9	24	4192	10.08	"	8	1	5233	<10.8	"	"	"	5633	<9.4	"	"	29	5991	<9.8
98	4	8	4388	9.15	"	"	21	5253	<11.7	"	"	9	5637	<10.8	"	"	30	5992	<9.4
"	5	21	4431	10.54	"	"	23	5255	<11.7	"	"	21	5649	<10.4	"	9	7	6000	<10.8
"	6	21	4462	11.42	"	9	1	5264	<11.8	"	"	22	5650	<11.7	"	"	10	6003	10.60
"	7	6	4477	11.62	"	"	"	5264	12.34	"	"	27	5655	<10.8	"	"	12	6005	10.46
"	10	3	4566	11.58	"	"	2	5265	12.17	"	10	1	5659	<11.2	"	"	15	6008	<9.8
"	"	"	4566	<11.8	"	"	"	5265	12.24	"	"	5	5663	<11.2	"	"	23	6016	9.44
99	2	24	4710	<11.8	"	"	19	5282	<9.9	"	"	7	5665	<11.7	"	10	6	6029	8.98
"	3	5	4719	<10.5	01	1	29	5414	11.96	"	"	8	5666	<11.4	"	"	9	6032	8.98
"	"	19	4733	<10.2	"	2	10	5426	<11.8	"	"	28	5686	<11.8	"	"	10	6033	9.02
"	"	20	4734	<11.8	"	"	14	5430	11.78	"	12	30	5749	10.96	"	"	23	6046	9.12
"	4	21	4766	<11.7	"	"	21	5437	<11.8	"	"	31	5750	10.96	"	12	31	6115	11.85
"	"	28	4773	<11.9															

The magnitudes given in Table V depend on the comparison stars contained in Table VI, which has the same form as Table III.

From the observations contained in Table V, the times of maximum given in the first column of Table VII have been derived. These maxima are nearly represented by the formula $2,410,106 + 238 E$. The corresponding values of E , and the computed maxima are given in the second and third columns. The fourth

TABLE VI.
COMPARISON STARS.

Des.	X	Y	Magn.
a	+ 800	+ 20	8.15
b	+1800	-1231	8.80
c	-2316	- 647	9.35
d	- 466	- 370	9.73
e	- 540	+1178	10.03
f	+ 438	+ 171	10.23
g	- 393	- 150	10.78
h	+ 468	- 655	11.03
k	+ 838	+ 491	11.15
l	- 507	- 207	11.60
m	- 377	+ 127	11.75
n	+ 129	- 484	12.07
o	+ 533	+ 318	12.52
p	- 59	+ 83	12.82

TABLE VII.
TIMES OF MAXIMUM.

Obs. M.	E	Comp. M.	O—C	Comp. M.	O—C
1526	6	1534	- 8	1525	+ 1
2246	9	1248	- 2	2248	- 2
2729	11	2724	+ 5	2728	+ 1
2962	12	2962	0	2967	- 5
3457	14	3438	+19	3445	+12
3683	15	3676	+ 7	3683	0
4173	17	4152	+21	4158	+15
4386	18	4390	- 4	4395	- 9
4858	20	4866	- 8	4868	-10
5104	21	5104	0	5104	0
5567	23	5580	-13	5574	- 7
5811	24	5818	- 7	5809	+ 2
6046	25	6056	-10	6043	+ 3

column gives the result found by subtracting the values in the third column from those in the first. The predominance of negative signs for the early and late observations indicates the existence of a third term. The last two columns give the values of the computed maxima, and residuals derived from the formula $2,410,068 + 244 E - 0.2 E^2$. The values of the epoch are the same in both cases.

It will be noticed that the average value of the residuals in the fourth column is ± 8 days, which is reduced to ± 5 days in the sixth column. The next maxima, according to the first formula, will occur on June 28, 1903, and February 21, 1904; according to the second formula, on June 11, 1903, and January 31, 1904.

MISSING ASTEROIDS.

Of the five hundred asteroids so far discovered, sixty-eight have not been seen during the last five years, while the last observation of twenty-five of them was from ten to thirty-five years ago. Evidently, there is great danger that many of them will be lost, and then it will be impossible to decide when one is observed

whether it is new or not. A discovery like that of Eros might thus remain unknown, the observer supposing that the object was an asteroid already found. Finding missing asteroids is evidently much more important than discovering new ones, since the former diminishes, the latter increases, the burden now upon astronomers of computing orbits for all. A list was accordingly prepared of the asteroids brighter than the magnitude 11.0, and which have not been seen for five years. The computed time of opposition of (21) Lutetia was January 13, 1903, magnitude 10.8. This asteroid was last seen in 1897. The opposition of (22) Kalliope was January 17, 1903, magnitude 9.6, last seen in 1896. Photographs were accordingly taken, with the results given in Table VIII. The number and

TABLE VIII.
MISSING ASTEROIDS.

Name.	Y.	M.	D.	G. M. T.	Ex.	R. A. 1855.		Dec. 1855.		C—O	C—O
(21) Lutetia	1903	1	21	13 43	20	<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>	<i>sec.</i>	<i>'</i>
" "	"	"	"	16 7	22	7	25.2	+ 24	40	+ 0.2	- 4
" "	"	"	22	13 20	20	7	24.1	+ 24	41	+ 0.2	- 2
(22) Kalliope	1903	1	21	14 31	20	7	44.4	+ 37	40	+ 2.4	+ 1
" "	"	"	"	16 56	22	7	44.3	+ 37	40	+ 2.4	+ 1
" "	"	"	22	15 27	20	7	43.2	+ 37	43	+ 2.6	0

name of the asteroid, the date of the plate, the Greenwich Mean Time, the length of exposure, and the approximate right ascension and declination for 1855, are given in the first six columns. The epoch 1855 is used, since the positions were determined by the configuration of the adjacent *Durchmusterung* stars. A greater degree of accuracy was not needed for the present purpose, since the ephemeris gives approximate positions only. If desired, positions of the degree of accuracy of meridian circle measures, could be obtained from these photographs. The last two columns give the differences found by subtracting the observed positions from those given by the ephemeris. They therefore indicate the errors of the latter.

In the case of Kalliope, the error is large enough to render the detection of the object difficult, except by photography.

EDWARD C. PICKERING.

JANUARY 26, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 70.

NOVA GEMINORUM BEFORE ITS DISCOVERY.

ON March 27, 1903, a cable message was received from Professor Kreutz, of Kiel, stating that an object which was probably a new star, but was possibly a variable, had been discovered by Professor Turner. Also, that on March 16 it was of the magnitude 8.0, while on February 16, it had not been seen (presumably on a photograph). Its apparent place was R.A. $6^h 37^m 48^s$, Dec. $+30^\circ 3'$. The grant from the Carnegie Institution permitted an examination to be made of the early photographs of the Henry Draper Memorial, and furnished the history of this object from its first appearance to the present time. An excellent photograph of the region, taken 1903, March $1^d 15^h 3^m$, G.M.T., showed stars of the magnitude 11.9, but no trace of the Nova was visible. A similar result was found from sixty-seven plates, the first taken March 3, 1890, the last on February 28, 1903, although nearly all of these plates showed stars fainter than the twelfth magnitude. One or more of these photographs were taken on each intermediate year. It did not therefore seem necessary to examine the other early plates of this region, a hundred or more in number. A plate, taken 1903, March $2^d 13^h 19^m$, showed stars of the ninth magnitude, but no trace of the Nova. The evenings of March 3, 4, and 5, were cloudy, but on a plate, taken March $6^d 14^h 28^m$, an object of the magnitude 5.08 appears in the given place. Plates taken on several later nights showed that the magnitude was gradually diminishing, as appears in Table I, which gives in successive columns, the date, the Greenwich Mean Time, the photographic magnitude of the Nova, and the initial of the observer. F, denotes Mrs. Fleming, and L, Miss Leland.

The photograph of March 6 has especial value since, so far as is known, it contains the first photograph of the Nova. The image is on the very edge of the plate, and accordingly was compared with fifteen other stars at about the same distance from the centre of the plate. The Nova was compared twice with each star by each observer. The value of the grade was much larger than usual, and equalled 0.21 and 0.33 for the two observers. The mean result for all was magnitude 5.08, with an average deviation, for the separate stars, of ± 0.26 . The magnitude on each

TABLE I.
PHOTOGRAPHIC MAGNITUDES.

Date.				G. M. T.	Magn.	Obs.	Date.				G. M. T.	Magn.	Obs.		
				<i>h</i>	<i>m</i>						<i>h</i>	<i>m</i>			
1903	March	1		15	3	<11.4	L	1903	March	14		14	14	7.42	F
"	"	2		14	31	< 9.5	F	"	"	"		"	"	7.34	L
"	"	6		14	28	4.97	F	"	"	"		16	20	7.32	F
"	"	"		"	"	5.20	L	"	"	"		"	"	7.34	L
"	"	11		15	18	6.76	F	"	"	15		13	44	7.27	F
"	"	12		14	25	7.06	F	"	"	"		14	53	7.57	F
"	"	"		15	25	7.16	F	"	"	"		"	"	7.46	L
"	"	13		14	52	7.12	F	"	"	25		13	26	7.94	L
"	"	"		14	52	7.17	F	"	"	"		13	39	8.08	F

of the other dates given in the table was found by comparison with six stars whose brightness was nearly equal to that of the Nova. These magnitudes were derived assuming that the photometric and photographic magnitudes were nearly the same for stars whose spectra were of the first type.

The evening of March 27 was cloudy and also the early part of March 28. One plate, however, taken on the latter date gave the magnitude, 8.34. Several photographs were taken on March 29, 31, and April 1, and gave the mean magnitudes, 8.24, 8.24, and 8.25. These magnitudes are based upon the results given in Table II which contains the designations, Durchmusterung numbers, rectangular coördinates expressed in seconds of arc with the Nova as an origin, and provisional photographic magnitudes of a sequence of comparison stars. It is probable that the fainter stars are really fainter than these magnitudes indicate, but the latter will serve to determine the relative changes in the Nova as it grows fainter, and thus render the results of different observers comparable. All the magnitudes can later be reduced to an absolute scale. They also serve to compare the faintest stars shown on early plates. Thus, the photograph taken March 1, 1903, shows star *t*, and also stars at least a tenth of a magnitude fainter. Star *n* does not appear. Hence this plate shows stars of the magnitude 11.9 and brighter.

The last plate in Table I is of interest since it was taken with an objective prism, and accordingly shows the spectra of the Nova and of the adjacent stars. Six bright lines are shown in the spectrum of the Nova, whose designations, assumed wavelengths, and intensities, calling the intensity of the line $H\gamma$, 10, are as follows:— $H\zeta$, 3889, 1; $H\epsilon$, 3970, 3; $H\delta$, 4102, 8; $H\gamma$, 4341, 10; —, 4643, 11; $H\beta$, 4862, 9.

TABLE II.

COMPARISON STARS.

Des.	DM.	x	y	Magn.	Des.	DM.	x	y	Magn.
a	+30° 1318	+ 716	+ 3187	7.28	p	.. ..	+ 4	+ 368	11.19
b	+30° 1300	....	....	7.76	q	.. ..	+ 308	- 132	11.41
c	+30° 1314	+ 274	+1949	7.98	r	.. ..	- 404	- 278	11.63
d	+30° 1320	+1021	+ 878	8.50	s	.. ..	+ 359	+ 345	11.73
e	+29° 1342	+1843	- 347	8.82	t	.. ..	- 224	+ 176	11.78
f	+30° 1316	+ 643	+ 552	9.14	u	.. ..	+ 467	+ 145	12.08
g	+30° 1306	-1006	+ 142	9.36	w	.. ..	- 254	+ 242	12.23
h	.. ..	+ 504	+ 289	9.71	x	.. ..	- 268	+ 92	12.45
	.. ..	+ 504	+ 297	9.71	y	.. ..	+ 270	+ 16	12.70
k	+30° 1302	-1923	+ 231	9.93	z	.. ..	+ 186	- 64	12.95
l	+30° 1309	- 456	+ 53	10.13	α	.. ..	+ 31	+ 97	13.05
m	+30° 1317	+ 638	- 327	10.41	β	.. ..	- 24	- 76	13.35
n	.. ..	- 311	- 47	10.66	γ	.. ..	+ 31	- 8	13.53
o	.. ..	+ 544	+ 197	11.01					

From this it appears that the spectrum resembles that of Nova Sagittarii on April 19, 1898. No dark lines are visible, but this is perhaps owing to the small dispersion.

The same lines, and having nearly the same intensities, appeared on similar photographs taken on March 29, 31, and April 1. They also showed the additional nebula line, 5003, which has the intensity 2 or 3, and is certainly brighter than H ζ . This line does not appear on the plate taken March 25, and indicates the first step in the change into a gaseous nebula. Three additional bright lines were detected in the later photographs, whose estimated wavelengths are about 4176, 4240, and 4462.

In the other new stars the appearance of line 5003 was followed by the diminution in intensity of the line H β , and the appearance and rapid increase in the nebula line, near H ζ , which finally became the strongest line in the spectrum.

A most important question in connection with the appearance of new stars is, whether such objects can come and go without detection by astronomers. Since the Henry Draper Memorial was established, nine new stars have been discovered. Six of them, Nova Persei No. 1, Nova Normae, Nova Carinae No. 2, Nova Centauri, Nova Sagittarii, and Nova Aquilae, were found in the regular examination of the Draper Memorial photographs, and probably all of them would otherwise have

escaped detection. Two, Nova Aurigae and Nova Persei No. 2, were bright, and were found visually by Dr. Anderson. The first of these might have escaped detection here, although numerous early charts were obtained which showed that it was visible to the naked eye during seven weeks before its discovery. The spectrum of Turner's Nova is so conspicuous on the plate taken on March 25, that when this plate was developed and examined it would doubtless have been found on it here, but for the prompt discovery and announcement by Professor Turner.

EDWARD C. PICKERING.

APRIL 3, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 71.

A PHOTOGRAPHIC MAP OF THE ENTIRE SKY.

THE collection of photographs at the Harvard College Observatory contains, in addition to the plates taken with the larger instruments, numerous photographs taken with two small anastigmatic lenses, each having an aperture of one inch, and a focal length of about thirteen inches. A region of more than thirty degrees square is covered by a single eight by ten inch plate. With exposures of one hour, stars as faint as the twelfth magnitude are, in some cases, obtained. Owing to the scale of the plates, identification of the individual stars would become difficult if, by using longer exposures, the number of stars were increased. One of these lenses is mounted at Cambridge, and is used principally for the northern stars. The other is similarly used for the southern stars at Arequipa. At each station two sets of photographs have been taken, the first having centres in declinations 0° , 30° , 60° , and 90° , and the second in declinations 15° , 45° , and 75° , the centres of the second set coinciding as nearly as possible with the corners of the first. An attempt is made to cover all parts of the sky, not too near the Sun, at least twice each month, once with each set. These photographs have proved unexpectedly useful here for determining the past as well as the present changes in light of variable stars, new stars, and similar objects. See Circular No. 69, and elsewhere. Of course, the small scale diminishes their value for measuring positions, although the minuteness of the images in part compensates for this difficulty.

The amount of useful material contained in these plates is so great that we are able to extract but a small portion of it, although an appropriation from the Carnegie Institution has, this year, permitted a great increase to be made. Various plans have been considered for placing copies of the photographs thus collected within the reach of astronomers. It was at first proposed to print a series of engravings on the same scale as the charts of the Durchmusterung. Numerous difficulties presented themselves, especially if an attempt was made to engrave the parallels and meridians upon the charts. The defects introduced by paper and ink are very troublesome, and are likely to differ in different copies. The variation in

intensity of images which can be represented on paper is small compared with that on glass, and finally, the expense would be large. The advantages of glass negatives are very great, especially to one accustomed to use them. They can be reproduced by contact printing so as to give results but slightly inferior to the original. A single contact print, forming a positive, with bright stars on a dark background, although more nearly resembling the sky itself, does not prove convenient in actual use. It cannot be superposed upon another positive, nor upon a paper map. A double contact print, however, furnishes a negative which is for some purposes nearly as useful as the original. Measurements of position or intensity of the images can be made, the cost is not large, and is nearly proportional to the number of copies furnished. A set of fifty-five of these prints on glass, covering the sky from the north to the south pole, has accordingly been prepared, and is described in Table I. A current number for designating the plate, and the approximate right ascension and declination of the centre, are given in the first three columns. The designation of the original negative is given in the fourth column. It consists of the letters indicating the series, and the number of the plate in that series. The plates taken with the anastigmatic lens at Cambridge are indicated by the letters AC, those at Arequipa by AM. The date, the Greenwich Mean Time, and the length of exposure, expressed in minutes, are given in the next three columns. Remarks on some of the plates follow the table. The position of any particular object is indicated by two numbers placed in brackets. The first gives the distance of the object, in millimetres, from the left hand edge of the exposed portion of the plate. The second number gives the corresponding distance from the lower edge of the exposed portion.

In the use of these plates certain suggestions may be made, especially for the benefit of those unaccustomed to astronomical photographs. To compare them with the sky, they should be examined with the glass side toward the eye. Objects of interest may then be conveniently marked on this side of the plate with a pen. The label is on the southern end of each plate, except in the cases of Nos. 1 and 54, which contain the north and south poles, respectively. Conspicuous configurations, like those of Orion, Ursa Major, and Scorpius, are easily recognized by inspection, aided when necessary by a small atlas. For the faint stars, a comparison may be made with the charts of the Durchmusterung, which are on nearly four times the scale. The plates may be examined with a reading glass or a two-inch positive eyepiece. The latter will, in almost all cases, serve to distinguish defects from actual star images. It will be noticed that images of bright stars are surrounded by sixteen rays, due to the iris diaphragm of the lens.

CIRCULAR NO. 71.

TABLE I.

CATALOGUE OF PLATES.

No.	R. A.	Dec.	Negative.	Date.	G. M. T.	Ex.	No.	R. A.	Dec.	Negative.	Date.	G. M. T.	Ex.
	<i>h. m.</i>	<i>o</i>		<i>y. m. d.</i>	<i>h. m.</i>	<i>m.</i>		<i>h. m.</i>	<i>o</i>		<i>y. m. d.</i>	<i>h. m.</i>	<i>m.</i>
1	0 00	+90	AC 2161	02, Jan.	4	22 43 39	29	14 00	0	AC 2547	02, May	13	16 35 73
2	0 00	+60	AC 1943	01, Nov.	2	17 51 63	30	16 00	"	AM 1420	" July	3	13 15 60
3	3 00	"	.....	.....		.. .. .	31	18 00	"	AM 1436	" "	9	14 18 60
4	6 00	"	.....	.....		.. .. .	32	20 00	"	AM 1439	" "	9	17 30 60
5	9 00	"	AC 3625	03, May	13	13 16 59	33	22 00	"	AM 1441	" "	9	19 39 60
6	12 00	"	AC 3466	" Mar.	31	18 42 71	34	0 00	-30	AM 1427	" "	3	20 53 60
7	15 00	"	AC 3620	" May	12	14 51 58	35	2 00	"	AM 1451	" "	10	20 56 61
8	18 00	"	AC 3629	" "	13	18 14 70	36	4 00	"	AM 1802	03, Jan.	16	15 55 68
9	21 00	"	AC 3630	" "	13	19 25 60	37	6 00	"	AM 1785	" "	3	17 33 60
10	0 00	+30	AC 2152	02, Jan.	4	13 06 57	38	8 00	"	AM 1798	" "	15	16 35 60
11	2 00	"	AC 124	98, Dec.	16	13 09 62	39	10 00	"	AM 1419	02, July	3	12 01 61
12	4 00	"	AC 2155	02, Jan.	4	16 16 59	40	12 00	"	AM 1443	" "	10	12 07 67
13	6 00	"	AC 3469	03, April	1	12 48 75	41	14 00	"	AM 1444	" "	10	13 15 60
14	8 00	"	AC 3363	" Feb.	26	16 16 59	42	16 00	"	AM 1452	" "	11	14 39 60
15	10 00	"	AC 2160	02, Jan.	4	21 55 56	43	18 00	"	AM 1461	" "	12	14 37 60
16	12 00	"	AC 3332	03, Feb.	20	21 04 67	44	20 00	"	AM 1463	" "	12	17 26 61
17	14 00	"	AC 1105	00, Dec.	28	22 04 68	45	22 00	"	AM 1440	" "	9	18 36 61
18	16 00	"	AC 252	99, Mar.	20	20 19 64	46	0 00	-60	AM 703	00, Nov.	1	13 37 61
19	18 00	"	AC 1013	00, Sept.	24	12 12 56	47	3 00	"	AM 1782	03, Jan.	3	14 12 64
20	20 00	"	AC 3353	03, Feb.	23	22 03 62	48	6 00	"	AM 712	00, Nov.	10	18 33 60
21	22 00	"	AC 1014	00, Sept.	24	13 16 69	49	9 00	"	AM 1247	02, May	15	12 43 60
22	0 00	0	AM 1569	02, "	25	15 32 58	50	12 00	"	AM 459	00, "	8	15 10 72
23	2 00	"	AM 151	99, "	14	18 45 60	51	15 00	"	AM 1469	02, July	14	14 13 60
24	4 00	"	AC 1093	00, Dec.	27	13 27 71	52	18 00	"	AM 809	01, May	27	17 48 61
25	6 00	"	AC 2156	02, Jan.	4	17 22 73	53	21 00	"	AM 1464	02, July	12	18 32 60
26	8 00	"	AC 513	99, Nov.	9	22 01 64	54	0 00	-85	AM 626	00, Sept.	3	17 11 60
27	10 00	"	AC 2518	02, May	2	14 19 65	55	14 00	-75	AM 1389	02, June	25	15 13 60
28	12 00	"	AM 1431	" July	8	12 09 65							

REMARKS.

- The position of the North Pole is [95, 104]. [97, 111], the Pole Star. The circular form and absence of diffraction rays show that [110, 118] is a defect.
- See No. 10.
- Owing to a change in the scheme of work, photographs have not been obtained in the position of this and of the following region. These omissions will be supplied in a few weeks, or as soon as their positions permit photographs to be obtained.
- See No. 3.
- [25, 89], ζ Ursae Majoris; also on No. 7. [172, 85].
- See No. 6.
- [48, 190], Nebula in Andromeda; also on No. 2. [47, 11].
- [117, 69], Pleiades, showing also the nebulosity surrounding them. Star 1 and perhaps m of the sequence given in Harvard Annals, XVIII, p. 153, appears on this plate. [131, 185], Nova Persei, No. 2. Nos. 54, 58, and 64, of Hagen's Catalogue are readily seen.
- [80, 58], Neptune. [39, 107], Nova Geminorum. Stars t and w of Circular No. 70 (Hagen 73 and 77) appear on this plate. Numerous clusters are also shown where it is crossed by the Milky Way. [82, 71], the cluster N. G. C. 2129.
- [40, 48], Praesepe.

17. [115, 92], the cluster Messier 3, N. G. C. 5272.
18. [51, 125], Messier 13, N. G. C. 6205, the cluster in Hercules.
19. [46, 163], the double stars ϵ and 5, Lyrae; also on Plate 20. [180, 169]. [31, 124], Messier 57, N. G. C. 6720, The Ring Nebula in Lyra; also on Plate 20. [175, 127].
20. See No. 19.
25. [134, 80], N. G. C. 1976, the great Nebula in Orion, [126, 91], ζ Orionis, showing the faint nebosity, N. G. C. 2024, north following it. [106, 105], α Orionis. The red color of this star is well shown by its faintness on the photograph. [40, 161], the cluster Messier 14, N. G. C. 2287. [31, 3], Sirius. The circle around this, and other very bright stars, is due to light reflected from the back of the plate.
30. [167, 116], the cluster Messier 5, N. G. C. 5904.
37. [74, 83], Pallas.
40. The fogging on the northern edge is due to the Moon.
42. [68, 119], α Scorpii. The red color of this star is well shown by its faintness on the photograph.
43. [166, 141], Uranus. [126, 89], the cluster Messier 7, N. G. C. 6475. [109, 75], the cluster Messier 6, N. G. C. 6405. [99, 144], the Triad Nebula, N. G. C. 6514. See Annals XXVI, p. 204, and Plate III. [96, 136], N. G. C. 6523.
44. [127, 136], Vesta. [113, 149], Saturn.
45. [169, 169], Jupiter. Satellite III is seen about half a millimetre to the left of it.
46. [87, 25], the cluster 47 Tucanae, N. G. C. 104. [76, 17], the Small Magellanic Cloud. See Annals, XXVI, p. 205, and Plate IV. [24, 102], Achernar, α Eridani. Next to Sirius, this is the brightest star in the sky; also on No. 47, [167, 102].
48. [115, 40], the Large Magellanic Cloud. See Annals, XXVI, p. 206, and Plate IV. [77, 137], Canopus.
- α Carinae. [13, 73], the cluster N. G. C. 2516; also on No. 49, [145, 86].
49. Several fine clusters appear on this plate, which are better shown on Plate 50.
50. [182, 49], the cluster N. G. C. 3114; also on Plate 49, [56, 94]. [153, 64], η Carinae or η Argus; also on Plate 49, [24, 88]. This is one of the most remarkable regions in the sky. See Annals XXVI, p. 206, and Plates V and VII. [138, 74], N. G. C. 3523; also on Plate 49, [6, 86]. [113, 61], N. G. C. 3766. The Southern Cross is well shown on this plate. See also Annals, XXVI, p. 203, and Plate II. [85, 79], δ Crucis. [79, 52], α Crucis. [72, 88], γ Crucis. [62, 71], β Crucis. The faintness of γ Crucis is due to its red color. This renders the Cross less conspicuous on the photograph than to the eye. [58, 66], the cluster κ Crucis, N. G. C. 4755. [7, 50], β Centauri. [6, 134], the cluster ω Centauri, N. G. C. 5139, the finest globular cluster in the sky.
51. [144, 90], β Centauri; also on No. 55, [99, 193]. [118, 91], α Centauri; also on No. 55, [72, 188]. So far as known, this is the nearest star in the sky. [42, 124], the cluster N. G. C. 6067.
54. As the latitude of the Arequipa station is $-16^{\circ}22'$, a good photograph could not be obtained if the declination of the centre of the plate was at -90° . Accordingly, this plate has been taken in R. A. $0^{\text{h}} 0^{\text{m}}$, Dec. $-83^{\circ}6'$. Plate 55, taken from the other set of photographs, has been added, to cover the region which would otherwise be omitted. The position of the South Pole is [92, 61]; also on No. 55, [96, 15]. [96, 64], σ Octantis; also on No. 55, [91, 14]. [84, 166], 47 Tucanae. [73, 157], the Small Magellanic Cloud.
55. See Nos. 51 and 54.

The cost of these plates will prevent the wide, gratuitous distribution of them, that is made of the Annals. In any case, this would not be advisable, since many would thus be placed where little or no use would be made of them. Copies of this set of photographs, consisting of fifty-five glass negatives, each eight by ten inches, will be supplied for \$15.00. Selected sets of ten plates, \$3.00. This is less than the actual cost, the balance being paid from the Advancement of Astronomical Science Fund of the Harvard Observatory. The privilege of increasing the price later is reserved. If the demand justifies it, copies of the second set of plates, whose centres are near the corners of these, will be issued later.

EDWARD C. PICKERING.

MAY 19, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 72.

INTENSITY OF SPECTRAL LINES.

For many years it has seemed to me that the determination of the intensity of the lines in the spectrum would be an investigation of great value. When Professor Rowland was planning his standard catalogue of lines in the solar spectrum, he consulted me regarding the advisability of giving their intensities as well as their positions. My reply was that the intensities were as important as in the case of stars, and that a whole science like that of stellar photometry and stellar variability might thus be developed.

The problem of determining the absolute intensity of spectral lines is one of great difficulty, but finding their relative intensities appears to be comparatively easy. In the case of bright lines, the relative intensities of adjacent lines may be found by the bolometer or similar instrument, or by a comparison of photographs, as described below. The comparison of dark lines on a light background, although apparently more difficult, has one great advantage, the background furnishes a convenient standard unit. We may call the intensity of a dark line unity if the light cut off from the background is equal to that of one ten-millionth of a millimetre, or one Ångström unit. This definition serves to compare lines which are broad or narrow, hazy or well defined. Two methods may be employed for the comparison. First, the selection of a sequence of standard lines whose intensity may be determined once for all, and the comparison of all others with them. Secondly, the construction of a standard scale with which each line may be compared directly. The second method has been employed here, since it promises to give approximate absolute values. The construction of the scale was entrusted to Mr. Edward S. King. A drawing was first made of a series of lines whose widths were proportional to 1, 2, 3, 4, etc., forming an arithmetical progression, and a reduced photograph was made of it. In this scale, the interval between 1 and 2 appeared much larger and was more easily subdivided than the higher intervals, some of which showed scarcely any difference. As in almost all physiological sensations, equal differences correspond to geometrical, rather than to arithmetical,

differences. A second scale was accordingly constructed, each line being about 1.26 as wide as that next it, so that the logarithms of their widths would differ by 0.1. This scale was then reduced rather more than twenty times. Prints were made from it, but were found to give images much more sharply defined than the lines in actual spectra. This was remedied by inserting one or more pieces of paper between the negative and sensitive paper in making the prints, and lines were thus obtained having any desired degree of haziness. The lines in Rowland's maps of the Solar Spectrum were found to be too hazy, and to differ too much in different portions of the same map, for satisfactory comparison. This difficulty was remedied by using the maps of Higgs. The Fraunhofer line E was selected, partly because it contained numerous lines of varying intensity well adapted to measurement, and partly because it was made the subject of special study by the writer in 1875 (Proc. Amer. Acad. XI. p. 273).

The line E appears on five of Higgs' Charts, Nos. 2, 3, 75, 76, and 79. The first two are taken from spectra of the second order, and on them one Ångström unit equals 0.14 cm. In the other three, taken from spectra of the third order, one unit equals 0.21 cm. We might expect that the linear width of the lines would be in the same proportion, but this is not the case. Owing to photographic irradiation, or other causes, the measured intensity of the lines is nearly the same in all. Although this shows that large errors may occur in the absolute intensity of the lines, it will not affect the relative intensity. A curve has been constructed for converting the scale measures into linear dimensions, assuming that the mean of the results derived from the two dispersions is the true value.

The results of these measures are given in Table I. The wave length, according to Higgs, is given in the first column. This does not appear to differ by a tenth of a unit on his different maps. The original measures on the five maps are given in the second column. Italics denote that when making the original measure the line was overlooked, but was found on reëxamination, when its existence on the other maps was known. The mean of the readings, and residuals from the mean are given in the third and fourth columns. The fifth column gives the concluded equivalent width of the line, in Ångström units, found graphically as described above. The sixth column gives the results of the comparison made in 1875, mentioned above. The dots indicate lines given by Kirchhoff, Ångström, Sharpless, Amory, Pickering, and Young, respectively.

A few additional lines were seen by some of the six observers mentioned above, so that the total numbers given by them, including those that are doubtful, are 12, 11, 32, 22, 30, and 37, respectively. The corresponding widths of the faintest

lines given are .064, .080, .012, .022, .014, and .009. The 36 lines in Table I correspond to a width of .009. Rowland's first map of the Solar Spectrum shows about 30 lines, the second edition 33 lines. The corresponding widths are .013 and .011.

TABLE I.
INTENSITY OF SPECTRAL LINES.

λ	Readings.					Mean.	Residuals.	Width.	Lines.
5261.8	9.4	9.5	9.5	9.6	9.5	9.50	1 0 0 1 0	.105	.....
2.1	8.5	8.6	8.5	8.6	8.5	8.54	0 1 0 1 0	.010	
2.3	..	..	8.7	8.8	8.7	8.73	.. 0 1 0	.016	
2.4	9.6	9.6	9.5	9.6	9.4	9.54	1 1 0 1 1	.114	.....
2.7	8.7	8.8	8.6	8.6	8.6	8.66	0 1 1 1 1	.013	?...
3.1	8.8	8.9	8.8	8.7	8.7	8.78	0 1 0 1 1	.018	
3.5	9.5	9.6	9.5	9.6	9.6	9.56	1 0 1 0 0	.119	.....
4.0	9.0	9.2	9.0	9.0	9.0	9.04	0 2 0 0 0	.038	.....
4.3	9.7	9.7	9.8	9.8	9.8	9.76	1 1 0 0 0	.201	.....
5.0	9.1	9.2	9.1	9.1	9.0	9.10	0 1 0 0 1	.045	.....
5.4	8.9	9.0	8.8	8.8	8.8	8.86	0 1 1 1 1	.022	.. ..
5.6	9.4	9.5	9.5	9.6	9.6	9.52	1 0 0 1 1	.109	.....
5.8	9.2	9.3	9.2	9.4	9.3	9.28	1 0 1 1 0	.064	.. ..
6.2	8.9	9.1	8.9	9.0	8.9	8.96	1 1 1 0 1	.030	.. ?
6.5	8.5	8.7	8.6	8.6	8.5	8.58	1 1 0 0 1	.010	..
6.7	9.6	9.7	9.6	9.8	9.8	9.70	1 0 1 1 1	.177	.....
7.4	8.8	9.0	8.8	9.0	8.8	8.88	1 1 1 1 1	.022	
8.5	8.9	9.1	9.0	9.0	8.9	8.98	1 1 0 0 1	.032	.....
8.8	8.8	8.6	8.8	8.8	8.8	8.76	0 2 0 0 0	.017	
9.2	8.6	8.7	8.6	8.5	8.5	8.58	0 1 0 1 1	.010	.. ..
9.7	9.8	9.9	9.8	9.9	9.9	9.86	1 0 1 0 0	.245	.....
5270.5	9.8	9.8	9.9	10.0	9.9	9.88	1 1 0 1 0	.256	.....
1.2	8.8	9.2	8.8	8.9	8.8	8.90	1 3 1 0 1	.023	.....
1.4	8.7	9.0	8.7	8.8	8.7	8.78	1 2 1 0 1	.018	.. ..
2.1	8.8	9.1	8.8	8.9	8.8	8.88	1 2 1 0 1	.022	.....
2.4	8.6	8.9	8.6	8.7	8.6	8.68	1 2 1 0 1	.014	.. ..
2.5	..	8.8	..	8.6	8.5	8.63	.. 2 .. 0 1	.012	
3.3	9.4	9.5	9.4	9.6	9.5	9.48	1 0 1 1 0	.100	.. ..
3.5	9.4	9.5	9.4	9.6	9.5	9.48	1 0 1 1 0	.100	.....
4.4	8.5	8.6	8.6	8.5	8.6	8.56	1 0 0 1 0	.010	
4.7	8.6	8.7	8.7	8.7	8.5	8.68	1 0 0 0 0	.014	.....
5.1	9.0	9.2	9.2	9.0	9.0	9.08	1 1 1 1 1	.042	.. ..
5.3	8.7	8.8	8.8	8.8	8.7	8.76	1 0 0 0 1	.017	
5.4	9.0	9.2	9.2	9.1	9.0	9.10	1 1 1 0 1	.045	.....
5.9	9.1	9.3	9.3	9.1	9.1	9.18	1 1 1 1 1	.049	.. ..
6.2	9.5	9.6	9.6	9.6	9.6	9.58	1 0 0 0 0	.123	.....

In all these cases only lines clearly seen are included. It is surprising how slight has been the gain during the last quarter of a century when we consider that it includes the invention of the concave grating. Nearly as faint lines were shown with a prism spectroscope in 1875, as can now be clearly seen in the best maps of the spectrum. Fainter lines are shown in the original negatives. Thus, Rowland's Catalogue of Wave Lengths contains 69 lines in this region. The average of the residuals in the fourth column is $\pm .06$.

EDWARD C. PICKERING.

JULY 29, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 73.

OPPOSITION OF EROS (433) IN 1905.

APPROXIMATE positions for the planet Eros during its opposition in 1903 were published in Circular No. 61. Mr. F. E. Seagrave has kindly computed the positions given in Table I, for intervals of forty days during the years 1904 and 1905. The elements used are those published in the Berlin Jahrbuch for 1905, page 428. The Julian Day, omitting the three left hand figures 241, the year, omitting the two left hand figures 19, the number of the month, and the day of the month are given in the first and second columns. The approximate right ascension and declination for 1900, and the logarithms of the distance of the Sun and of the Earth are given in the four remaining columns.

TABLE I.
COMPUTED POSITIONS.

J. D.	Date. 1904.			R. A. 1900.	Dec. 1900.	log r.	log Δ.	J. D.	Date. 1905.			R. A. 1900.	Dec. 1900.	log r.	log Δ.
	y.	m.	d.	h.	m.	o	°		y.	m.	d.	h.	m.	o	°
6481	04	1	1	21	8.4	-12	8	0.2292	0.3784	6881	05	2	4	17	56.3
6521	"	2	10	22	40.5	-2	41	0.2057	0.3968	6921	"	3	16	19	41.3
6561	"	3	21	0	18.5	+8	39	0.1737	0.3923	6961	"	4	25	21	0.7
6601	"	4	30	2	11.8	+19	53	0.1346	0.3727	7001	"	6	4	21	45.5
6641	"	6	9	4	31.3	+27	10	0.0935	0.3480	7041	"	7	14	21	32.0
6681	"	7	19	7	9.9	+25	13	0.0620	0.3288	7081	"	8	23	20	23.8
6721	"	8	28	9	38.4	+13	15	0.0554	0.3220	7121	"	10	2	20	6.4
6761	"	10	7	11	48.2	-3	11	0.0777	0.3267	7161	"	11	11	20	52.2
6801	"	11	16	13	51.0	-18	4	0.1165	0.3346	7201	"	12	21	22	9.5
6841	"	12	26	15	55.2	-27	39	0.1574	0.3338					1	33

From the values given in Table I, an approximate interpolation was made, substantially as described in Circular No. 61. Table II gives in the successive columns for each ten days, the Julian Day, the date, the right ascension and declination for 1900, the logarithms of the distances of the Sun and Earth, and the

It will be noticed that this is one of the most unfavorable oppositions that can occur. Eros is in aphelion on July 5, 1905, and in opposition on August 7, 1905. At no time during 1904 and 1905 is it brighter than the twelfth magnitude. The most important observations that can be made during this opposition are those of the variation in light, both visually and photographically. Excellent light curves of Eros have, however, been obtained this year by Professor Bailey at Arequipa, with the 13-inch Boyden Telescope, although the planet was fainter than the twelfth magnitude. It seems probable therefore that valuable observations may be obtained in 1905, with the numerous large reflectors and refractors available. The planet's position in the sky will be, in general, nearly opposite to that it had in the spring of 1901, when its variability was discovered.

EDWARD C. PICKERING.

SEPTEMBER 12, 1903.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 74.

VARIABLE STARS OF LONG PERIOD.

THE method of observing variable stars of long period at the Harvard College Observatory, is described in the *Annals*, Volume XXXVII. In general, a sequence of comparison stars is selected having intervals of about a third of a magnitude, and the variable is compared by Argelander's method with a brighter and a fainter star, at least once a month. Photometric measures of the light of these comparison stars permit all the results to be reduced to a uniform photometric scale. Observations of seventy-four of these variables, from 1889 to 1901, are discussed in Volume XXXVII.

When the measures made at different observatories on the same night are compared, they often differ by half a magnitude or more. A large part of these errors is due to the red color of many variables of this class, and will depend upon the observer, the size of the telescope, the color of the star, and other causes. Often observers will not agree regarding the two stars of the sequence between which the variable should be included. The resulting magnitudes would therefore be nearly as good if the observer merely stated that the variable was surely brighter than one star and fainter than that next it in the sequence, without attempting to estimate grades. At least, considering the large number of variables of which we have no current observations, our knowledge of their variations could thus be greatly and easily increased.

Owing to the great range in brightness of many of these stars and the uncertainty in our knowledge of the laws regulating their variations these errors are not very serious, and it is much to be desired that all known variables of this class, about four hundred in number, should be observed according to the same system. The case is entirely different from that of the variables of short period, and from that of variables of the Algol type, which vary so regularly and their light curves can be determined so accurately by photometric methods, that observations of them by

Argelander's method are of less importance. For these stars, it is better to determine the form of light curve once for all photometrically, and then measure the period and its variations by occasional observations when the star is changing most rapidly.

Table I contains a list of the variables of long period. The first two columns give the designations and names of the stars taken from the first and third columns of the table given on page 96 of Volume XLVIII, and adding a few objects discovered later. The designation gives the hour and minute of right ascension and the degree of declination of each star, for 1900, southern declinations being indicated by *Italics*. The third column furnishes additional information regarding each variable. The number indicates the Series of Father Hagen in which the variable occurs, 6 denoting observations supplementary to Series 1, 2, and 3. The letter *p* denotes that the star is one of the polar stars discussed in Volume XXXVII, Part I; *a* denotes the fifty-eight additional stars contained in Volume XXXVII, Part II; *s* denotes other stars for which sequences have been selected and measured by the writer with the 12-inch Meridian Photometer; *h* denotes stars discovered at Harvard for which sequences have been selected from the photographs; *r* denotes the stars for which faint standards have been selected and measured by the aid of the Rumford Fund, by cooperation of the Yerkes, Lick, McCormick, Halsted, and Harvard Observatories; *d* denotes the stars for which enlargements have been made of the Durchmusterung charts, as described in Circular No. 53; *f* denotes stars which are followed, if possible, once a month either at Cambridge or Arequipa. Similar observations are made of all the stars marked *a* and *p*. The star *092448* should be omitted.

The positions and photometric magnitudes of the sequences for the stars marked *p* and *a* will be found in Volume XXXVII. The positions and photographic magnitudes of the sequences for the stars marked *h* are in process of publication in Volume XLVII. Photometric measures have been made by the writer, with the 12-inch Meridian Photometer, of all the sequences for stars in Hagen's Series 1, 2, 3, 4, and 5, except those marked *p* and *a*, for which other photometers have been used. Photometric measures are in progress of sequences for stars marked *h* and north of declination -25° , and will shortly be undertaken for those marked 6. In general, therefore, sequences have been selected, for nearly all the stars marked with a letter or figure, except those marked 6. Photometric measurements have been made of nearly all of these except those marked *h*.

TABLE I.
VARIABLE STARS OF LONG PERIOD.

Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.
000339	V Sculpt.	h	024217	T Arietis	4 s	054974	V Camelop.		083350	— Urs. Maj.	h
001032	S Sculpt.	hf	024356	W Persei	4 s	054920	U Orionis	2 ad	084127	R Pyxidis	
001726	T Androm.	3 ad	025050	R Horologii	hf	055353	Z Aurigae		084803	S Hydrae	2 ad
001755	T Cassiop.	3 pd	025751	T Horologii		055686	R Octantis	hf	085008	T Hydrae	1 ard
001862	S Tucanae	h	030514	U Arietis	2 sr	060450	X Aurigae	6	085120	T Cancri	4 s
001838	R Androm.	3 ad	031401	X Ceti	6 hf	061647	V Aurigae	3 sr	090024	S Pyxidis	f
001909	S Ceti	1 ard	032043	Y Persei		061702	V Monoc.	4, 6 s	090425	W Cancri	6 hf
002438a	T Sculpt.		032335	R Persei	3 sr	063308	R Monoc.	6	091868	RW Carin.	h
002438b	RR Sculpt.		034124	S Fornacis		063558	S Lyncis	6	092048	— Velorum	h
002546	T Phoenicis	h	034625	U Eridani		064030	X Gemin.	6	092448	— Velorum	
002833	W Sculpt.		035124	T Eridani	hf	064707	W Monoc.		092551	Y Velorum	
003179	Y Cephei		040725	W Eridani	hf	065111	Y Monoc.	6	092962	R Carinae	5 f
004047	U Cassiop.	3 srf	041619	T Tauri	2 s	065208	X Monoc.	4 hf	093014	X Hydrae	6
004435	V Androm.	6	042215	W Tauri	2 s	065355	R Lyncis	3 pd	093178	Y Draconis	
004435	X Sculpt.		042209	R Tauri	2 ad	070122a	R Gemin.	2 ard	093934	R Leo. Min.	3 ard
004958	W Cassiop.		042309	S Tauri	2 a	070122b	Z Gemin.		094023	RR Hydrae	
005475	— Tucanae	h	043065	T Camelop.	3 s	070109	V Can. Min.	6 hf	094211	R Leonis	4 ad
010630	U Sculpt.		043274	X Camelop.		070310	R Can. Min.	4 s	094622	Y Hydrae	4 h
010940	U Androm.	6	043263	R Reticuli	f	070311	— Can. Maj.	h	094953	Z Velorum	
011272	S Cassiop.	3 prd	043562	R Doradus	f	070772	R Volantis		095421	V Leonis	2 s
011208	S Piscium	2 sr	043738	R Caeli	hf	071044	L ² Puppis	5 f	095458	RR Carinae	hf
011712	U Piscium	2 s	044349	R Pictoris	hf	071201	RR Monoc.		095563	RV Carinae	
012233	R Sculpt.	f	044617	V Tauri	2 sr	071713	V Gemin.	2 s	100661	S Carinae	f
012502	R Piscium	2 ad	045307	R Orionis	2 s	072708	S Can. Min.	2 ad	101058	Z Carinae	hf
013238	RU Androm.		045514	R Leporis	4 s	072820b	Z Puppis		101153	W Velorum	
013338	Y Androm.	6	050022	T Leporis	6 hf	072811	T Can. Min.	2 s	103212	U Hydrae	
014958	X Cassiop.	6	050003	V Orionis	2 s	072820a	X Puppis		103270	— Carinae	h
015254	U Persei	3 sh	050848	S Pictoris	h	073173	S Volantis		103361	RX Carinae	h
015912	S Arietis	2 s	050953	R Aurigae	3 pd	073508	U Can. Min.	2 s	103769	R Urs. Maj.	3 pd
021024	R Arietis	2 ad	051247	— Pictoris	h	073723	S Gemin.	2 s	104628	RS Hydrae	
021143	W Androm.	6	051533	T Columbae	h	074241	W Puppis	h	104620	V Hydrae	4 s
021281	Z Cephei	4	052036	W Aurigae	6	074323	T Gemin.	2 s	104814	W Leonis	2 sr
021403	o Ceti	4, 5 ad	052034	S Aurigae	3 s	074922	U Gemin.	2	110506	S Leonis	2 s
021558	S Persei	3 pd	052404	S Orionis	1 sr	075612	U Puppis	1 srf	111661	RS Cent.	h
022000	R Ceti	1 ard	053068	S Camelop.	3 s	080138	RT Puppis	h	114441	X Centauri	h
022260	S Horologii	h	053005a	T Orionis	1 s	080322	RU Puppis	hf	115058	W Centauri	h
022426	R Fornacis		053326	RR Tauri	6	081112	R Cancri	2 ad	115919	R Com. Ber.	ad
022741	X Eridani		053531	U Aurigae	3 s	081617	V Cancri	2 ard	120206	RW Virg.	4 h
022813	U Ceti	4 ad	054331	S Columbae		082476	R Chamael.	h	120905	T Virginis	1 ard
022980	RR Cephei		054615	Z Tauri	6	082405	RT Hydrae	4 hf	121418	R Corvi	1 ad
023133	R Triang.	3 sh	054629	R Columbae	hf	083019	U Cancri	2 s	122532	T Can. Ven.	6

Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.
122657	U Crucis	h	151731	S Cor. Bor.	3 ad	165636	RT Scorpii	hf	190967	U Draconis	
122854	U Centauri	hf	151822	RS Librae	6 hf	170215	R Ophiuchi	1 ad	191007	W Aquilae	
122803	Y Virginis	1 ad	152714	RU Librae	6 hf	170627	RT Herc.		191033	RY Sagitt.	
123160	T Urs. Maj.	3 prd	152849	R Normae		170833	RW Scorpii	hf	191017	T Sagitt.	1 s
123307	R Virginis	4 ad	153020	X Librae	1 s	171401	Z Ophiuchi	6 hf	191050	V Telesc.	h
123961	S Urs. Maj.	3, 4 pd	153215	W Librae	1 s	171723	RS Herc.	6	191019	R Sagitt.	1 ad
124204	RU Virgin.	6	153378	S Urs. Min.	h	171843	SW Scorpii	h	191350	TZ Cygni	
124606	U Virginis	2 ard	153620	U Librae	1 s	172586	S Octantis	hf	191319	S Sagitt.	1 s
125057	- Crucis	h	153654	T Normae		173543	RU Scorpii	hf	191321	Z Sagitt.	1 sr
125705	RT Virgin.	hf	154020	Z Librae	1 s	174162	W Pavonis	h	191637	U Lyrae	
130212	RV Virgin.		154428	R Cor. Bor.	3 a	174135	SV Scorpii		191717	T Sagittae	4 s
131283	U Octantis		154639	V Cor. Bor.	3 s	174551	U Arae	h	192928	TY Cygni	
131561	- Centauri	h	154615	R Serpentis	2 sr	174748	V Arae	h	193311	RT Aquilae	
132202	V Virginis	1 ad	154736	R Lupi		175458	T Draconis	4 s	193449	R Cygni	3 ad
132422	R Hydrae	4, 5 ad	154715	R Librae	6	175519	RY Herc.		193509	RV Aquilae	
132706	S Virginis	1 ard	155018	RR Librae	1 sr	175654	V Draconis		193972	T Pavonis	h
133155	RV Cent.	h	155823	RZ Scorpii		180122	RW Herc.		194048	RT Cygni	4 s h
133273	T Urs. Min.		160021	X Scorpii	1 s	180363	R Pavonis	h	194350	W Telesc.	
133633	T Centauri	f	160150	RR Herc.	4 s	180565	W Draconis		194348	TU Cygni	
134236	RT Cent.		160118	R Herculis	2 ad	180531	T Herculis	3 ad	194604	X Aquilae	hf
134327	W Hydrae		160210	U Serpentis	6 hf	180666	X Draconis		194632	X Cygni	3, 5 ard
134440	R Can. Ven.	3 ad	160221	X Scorpii	1 s	180742	Y Cor. Aus.	h	194659	S Pavonis	h
134536	RX Cent.		160519	W Scorpii	1 s	181136	W Lyrae		194929	RR Sagitt.	hf
134677	T Apodis		160524	RX Scorpii		181949	T Telescopii	h	195142	RU Sagitt.	hf
135908	RR Virgin.	1 s	160625	RU Herc.	6	182133	RV Sagitt.	hf	195202	RR Aquilae	h
140113	Z Bootis	hf	161138	W Cor. Bor.		182345	- Cor. Aus.	h	195308	RS Aquilae	hf
140512	Z Virginis	1 s	161122a	R Scorpii	1 ard	182306	T Serpentis	6	195855	S Telescopii	
140528	RU Hydrae		161122b	S Scorpii	1 ard	183225	RZ Herc.		195849	Z Cygni	3 sf
140959	R Centauri	5 f	161607	W Ophiuchi	6	183308	X Ophiuchi	4 s	200360	X Pavonis	h
141549	T Lupi	h	161751	X Normae	h	183437	U Cor. Aus.	h	200357	S Cygni	6 pd
141954	S Bootis	3 prd	162112	V Ophiuchi	4 s	184134	RY Lyrae		200514	R Capric.	1 s
142205	RS Virginis	6 hf	162119	U Herculis	2 ad	184243	RW Lyrae		200715a	S Aquilae	4 s
142584	R Camelop.	3 prd	162319	Y Scorpii	6	185032	RX Lyrae		200747	R Telesc.	hf
142539	V Bootis	4 s	162815	T Ophiuchi	1 s	185537a	R Cor. Aus.	f	200812	RU Aquilae	
143227	R Bootis	3 ad	162807	SS Herculis	6	185512	ST Sagitt.	4 hf	200844	RZ Sagitt.	
143417	V Librae	1 s	162816	S Ophiuchi	1 s	185634	Z Lyrae		200822	W Capric.	1 s
144646	S Lupi	h	163137	W Herculis	3 ar	185737	RT Lyrae		200906	Z Aquilae	6
144918	U Bootis	2 s	163266	R Draconis	3 prd	190049	U Telesc.	h	201008	R Delphini	2 ad
145971	S Apodis	h	163172	R Urs. Min.	4 pd	190108	R Aquilae	2 sr	201139	RT Sagitt.	hf
150018	RT Librae	6	164319	RR Oph.		190529	V Lyrae		201152	X Telesc.	
150519	T Librae	1 s	164715	S Herculis	2 ard	190819	RW Sagitt.	hf	201121	RT Capric.	f
150605	Y Librae		164844	RS Scorpii	hf	190818	RX Sagitt.	hf	201130	SX Cygni	4
150850	W Lupi	h	164832	SS Scorpii		190925	S Lyrae		201437b	- Cygni	
151520	S Librae	1 ad	165030	RR Scorpii	hf	190941	RU Lyrae		201520	V Sagittae	
151714	S Serpentis	2 ad	165631	RV Herc.		190933	RS Lyrae		201647	U Cygni	4 ad

Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.	Design.	Name.	Rem.
202128	T Microsc.	h	204954	S Indi	hf	213678	S Cephei	3 pd	223841	R Lacertae	3 sr
202240	U Microsc.	h	205017	X Delphini		213753	RU Cygni	4 s	225120	S Aquarii	1 ard
202539	RW Cygni	4 s	205030	UX Cygni		213843	SS Cygni	6 abd	225914	- Pegasi	h
202622	RU Capric.	6	205627	RR Capric.		214024	RR Pegasi		230110	R Pegasi	2 ard
202817	Z Delphini		205782	T Octantis	hf	214247	R Gruis	hf	230759	V Cassiop.	6
202946	SZ Cygni		205923	R Vulpec.	2 ard	215605	V Pegasi	6 hf	231425	W Pegasi	4 s
202954	ST Cygni		210129	TW Cygni	6	215717	U Aquarii	1 s	231508	S Pegasi	2 ad
203429	R Microsc.	hf	210124	V Capric.	1 sr	215328	SPisc. Aus.		233315	R Aquarii	1 ad
203611	Y Delphini		210221	X Capric.	1 s	215934	RT Pegasi		233956	Z Cassiop.	
203847	V Cygni	3 ad	210382	X Cephei	6	220412	T Pegasi	2 s	234716	Z Aquarii	4 hf
203816	S Delphini	2 s	210516	Z Capric.	6	220613	Y Pegasi	4	235053	RR Cassiop.	
203905	Y Aquarii	6	210504	RS Aquarii	6	220714	RS Pegasi	4	235150	R Phoenicis	f
204016	T Delphini	2 s	210868	T Cephei	4 pd	221230	R Pisc. Aus.	f	235265	R Tucanae	hf
204104	W Aquarii	6 hf	210812	R Equulei	4	221321	X Aquarii	6 hf	235209	V Ceti	1 s
204102	V Aquarii	4 s	210903	RR Aquarii	6	221722	RT Aquarii	6 h	235350	R Cassiop.	4 pd
204215	U Capric.	1 s	211614	X Pegasi		221733	T Lacertae		235357	S Phoenicis	h
204318	V Delphini	6 hf	211615	T Capric.	1 s	221938	T Gruis	hf	235525	Z Pegasi	h
204405	T Aquarii	1 ad	212030	S Microsc.		221948	S Gruis	hf	235715	W Ceti	6
204763	U Pavonis	h	212314	Y Capric.	1 s	222439	S Lacertae	3 shf	235855	Y Cassiop.	6 hf
204846	RZ Cygni	6	213244	W Cygni		222867	R Indi	f			

The positions of the stars in the sequences not given in Volumes XXXVII and XLVII are shown in Table II. The designation of the variable is given in the first column, and the successive columns give the difference in right ascension expressed in seconds of time, and in declination expressed in minutes of arc and tenths, of each star from the variable. When the star precedes or is south of the variable, the corresponding coördinate is placed in *Italics*. For stars contained in Hagen's Series 1, 2, and 3, the positions are taken from that work and the order is that of the Hagen numbers. For other stars, the Durchmusterung positions and magnitudes are used for the brighter stars, and estimates for the fainter. It is suggested that these stars be provisionally designated, *a*, *b*, *c*, etc., and that the final order and designations be applied when the final magnitudes are deduced. In many cases, the intervals of the sequence will prove too large, and additional stars may then be inserted. Thus, if two stars were needed between *c* and *d*, they could be called *c'* and *c''*. It is extremely desirable, to avoid confusion, that designations once used should not be changed until the final notation can be adopted and published, so that any changes may be made once for all.

TABLE II.
ADDITIONAL SEQUENCES.

Design.	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>	<i>s.</i>	<i>f.</i>
004047	57	26.4	30	0.5	123	3.9	106	18.3	16	0.9	44	16.8	1	2.2
	27	5.1	3	11.4	71	2.1	35	3.0	14	2.9				
011208	114	32.3	117	9.6	39	26.7	19	2.7	39	0.3	30	7.8	54	7.8
	73	4.8	50	5.7	14	1.8	58	12.0	1	0.6			28	12.3
011712	60	16.2	23	14.1	15	13.2	25	7.2	48	15.9	21	5.1	20	16.2
	38	7.2	0	13.8	58	12.7							37	3.9
015254	229	7.4	80	13.0	140	1.8	81	29.1	149	5.8	26	8.8	50	9.2
	31	23.0	34	10.9	12	1.3	40	4.8	41	0.4	13	5.6	1	9.9
	50	6.0	6	3.1	9	1.8							7	8.3
015912	133	9.6	151	20.8	97	5.2	11	5.5	22	4.4	51	5.6	19	2.2
	1	11.2											53	14.6
023133	247	16.3	73	27.5	198	4.9	92	6.6	119	6.2	147	21.3	49	29.0
	28	3.2	24	11.8	64	2.3	21	15.4	31	21.3	68	0.7	0	3.1
	39	8.7	56	0.1	1	2.4							4	6.6
024217	151	31.4	56	14.0	52	19.5	36	14.0	13	25.9	24	5.2	40	11.3
	49	0.1	1	6.4									189	13.4
024356	83	2.9	110	16.6	77	25.1	69	4.1	28	18.4	22	22.1	5	1.5
	96	6.9	28	4.9	12	11.4							117	28.9
030514	140	33.0	16	32.9	64	34.0	14	20.2	59	2.4	81	14.7	63	2.2
	26	8.2	34	6.9	12	3.0	11	7.2					2	11.4
032335	75	8.0	155	0.3	108	23.2	72	1.1	44	0.2	87	12.1	19	7.5
	42	12.8	43	10.6	28	4.8	16	8.7	14	6.6	1	5.4	13	2.0
041619	106	18.6	16	3.9	83	7.5	88	16.8	51	3.3	67	1.7	14	3.0
042215	62	6.9	21	27.9	23	15.6	116	37.1	110	0.3	20	0.6	52	15.0
	31	6.0	55	3.6									16	3.0
043065	582	24.0	146	35.6	87	23.1	49	14.1	106	4.1	106	6.3	111	2.1
	9	3.8	100	14.7	9	0.7	35	2.9	108	0.9	47	1.8	86	6.5
	38	6.7											58	2.9
044617	98	20.7	121	30.5	103	0.9	35	12.3	43	9.9	6	6.3	21	4.2
	22	14.7	54	14.4	17	8.4	22	10.2	12	4.2	29	0.9	11	10.3
045307	136	14.7	55	14.4	4	16.8	80	18.3	13	19.5	11	23.7	12	3.6
	41	7.2											27	1.5
045514	187	35.0	59	1.4	13	56.3	179	53.0	13	18.2	16	34.0	67	1.3
	53	22.9	28	18.0									33	43.8
050003	2	18.3	40	29.3	24	4.2	80	9.6	39	9.0	71	5.7	10	3.3
	8	9.6	15	11.1	30	6.3	5	0.9	12	3.1	5	4.2	32	14.9
052034	97	2.1	39	12.1	101	17.7	152	8.3	105	1.0	59	16.6	22	3.0
	2	22.2	18	3.3	10	5.7	47	1.5	65	0.2	1	4.9	60	2.4
	21	3.7	18	1.8	14	3.6	2	5.0	1	0.9			6	0.8
052404	27	0.3	81	34.5	125	6.6	105	15.3	48	21.3	15	6.3	2	0.4
	29	8.1	15	0.9	27	7.5	3	3.3	58	4.2			60	0.0

Design.	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
053068	203	4.9	269	4.2	202	11.0	205	3.9	112	2.2	124	6.9	39	1.9	14	0.7
	167	2.8	52	5.9	44	3.8										
053005 a	25	10.2	4	9.6	40	17.7	37	4.2	20	25.2	19	4.5	48	0.0	0	12.0
	9	0.3	34	10.8	19	0.9	37	11.4	39	9.6						
053531	123	2.1	125	8.7	4	10.0	89	3.6	15	26.9	98	1.3	64	0.3	32	3.9
	68	5.6	82	10.9	11	1.0	22	0.5	61	9.6	15	2.8	30	0.3	6	9.5
061647	32	34.9	174	29.5	32	16.7	161	14.5	71	5.5	46	13.1	45	8.0	43	9.5
	85	12.1	18	6.4	62	9.3	18	10.8	14	3.9	5	7.8	14	7.5		
061702	13	30.9	86	58.1	30	42.3	44	9.9	26	27.0	78	13.1	174	3.9	147	3.1
	0	47.7	30	18.7												
070310	130	38.2	187	29.8	14	1.3	97	9.2	17	38.8	12	17.3	32	7.1	43	19.1
	29	39.9	54	21.9												
071713	109	3.3	37	7.3	115	2.9	38	2.1	19	1.5	45	3.6	8	20.7	20	6.0
	41	2.7	38	0.9	1	2.7	21	5.4	0	2.9	0	1.5	7	3.3	7	0.9
072811	79	7.5	42	1.5	27	17.2	97	12.1	34	12.6	57	10.3	31	3.5	42	3.1
	78	8.7	17	6.3	32	6.2	23	3.0	9	4.0	21	4.0	20	3.7		
073508	4	3.0	32	0.6	50	21.0	43	2.7	37	6.7	25	3.1	23	1.5	46	4.8
	16	2.4														
073723	90	6.0	78	4.2	0	10.2	9	5.8	84	9.9	17	1.8	63	8.7	19	2.1
	41	0.3	3	11.1	34	2.4	29	4.0								
074323	81	26.0	17	32.3	87	3.1	38	21.0	66	17.7	118	2.9	66	0.9	8	5.3
	50	3.3	41	0.3	38	2.1	1	1.5	6	3.1						
075612	65	1.2	76	2.7	34	3.0	65	17.7	44	3.0	25	3.9	61	7.8	26	3.3
	42	4.2	4	4.5	22	4.5	7	8.4								
083019	120	22.6	82	30.1	62	0.6	55	25.4	44	4.3	106	22.4	48	2.4	37	15.2
	2	16.7	70	2.1	97	11.9	36	17.3	32	12.9	16	11.7	12	4.8	36	6.3
	12	7.6	37	6.7	26	11.5										
085120	15	20.6	197	31.8	161	22.8	146	15.8	119	20.9	37	3.0	62	15.9	220	53.8
	60	18.6	26	18.3												
095421	118	16.9	32	11.8	94	8.5	91	3.0	15	10.1	90	22.1	56	11.2	24	7.9
	4	5.3	3	0.7	25	4.3	19	2.0	14	1.0						
104620	196	4.6	22	16.6	131	9.4	244	15.9	78	8.3	86	4.8	232	8.8	181	19.2
	49	12.2	15	0.4	20	14.4										
104814	113	9.0	126	3.0	69	21.6	72	26.4	109	12.3	24	14.4	18	4.2	69	0.7
	57	5.7	51	2.7	34	6.6	16	2.1	16	8.1	23	8.7				
110506	125	28.1	113	24.2	30	21.6	48	12.3	69	4.2	50	8.4	62	0.3	28	6.6
	51	0.9	5	14.1	5	1.0										
135908	18	8.7	113	18.6	5	24.0	47	1.8	47	8.4	28	2.4	4	6.9	34	10.2
	6	2.1	8	6.6												
140512	11	2.4	21	0.1	68	8.8	29	10.3	5	8.9	7	2.7	42	9.5	2	5.1
	22	12.5														
142539	95	62.9	91	50.0	56	8.3	83	38.5	39	20.1	34	20.6	121	34.9	11	20.9
	126	0.7	61	3.8												
143417	22	12.6	68	3.9	54	5.4	14	0.6	33	0.3	47	3.3	27	5.1	22	8.1
144918	47	0.3	114	15.4	41	8.5	27	14.4	2	4.2	35	6.2	35	2.7	46	5.3

Design.	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$	$\Delta\alpha$	$\Delta\delta$
	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>	<i>s.</i>	<i>°</i>
195849	93	5.5	84	33.3										
	106	15.7	108	25.1	38	30.6	29	12.4	41	2.3	103	8.3	141	15.3
	21	1.9	2	9.9	14	8.8	7	8.4	26	0.6	14	0.8	3	12.1
	31	3.5	15	8.8									84	3.5
200514	90	29.0	92	0.3	103	0.6	16	27.0	65	7.8	15	8.1	40	3.6
	17	16.8	35	0.9	28	3.0	30	1.8	5	2.4			44	3.0
200715 a	71	24.0	149	28.2	115	34.8	88	42.1	14	26.0	23	30.6	13	3.2
	23	10.3	43	9.3									2	1.4
200822	11	3.7	72	4.5	4	25.4	5	3.6	25	24.9	37	15.2	6	9.1
	46	2.0	26	2.8	0	8.5							20	0.1
202539	214	2.9	34	7.1	66	23.0	101	4.6	6	2.0	13	7.0	148	18.5
	11	21.8	46	15.4									1	22.5
203816	55	29.3	23	8.4	1	0.9	108	5.1	15	26.9	14	9.3	91	22.2
	14	5.4	14	1.5	49	6.1	3	8.4	31	6.0	22	3.3	52	12.0
	30	3.0											55	2.1
204016	66	30.0	117	6.3	31	13.5	107	4.0	65	5.7	24	0.3	47	2.7
	12	0.0	33	2.7	4	5.1	10	2.7	10	8.1			41	7.2
204102	190	1.0	45	35.8	106	24.3	48	18.8	36	4.3	23	19.5	88	4.8
	2	27.5	5	0.8									62	22.3
204215	19	6.9	60	13.2	56	17.7	61	14.4	31	6.9	35	0.9	44	9.3
	39	0.0	11	7.2									35	6.3
210124	96	17.7	55	17.4	161	18.6	97	16.2	57	19.8	45	20.3	22	6.8
	44	2.4	13	23.6	48	8.1	13	20.3					122	0.2
210221	3	20.1	85	27.5	37	14.1	55	9.6	69	9.0	47	6.0	13	8.4
211615	31	0.6	71	20.4	94	7.5	5	4.4	33	23.6	5	14.1	43	6.5
	13	11.7	15	7.2	47	4.2	12	1.8					55	12.6
212814	6	29.3	21	4.5	36	27.5	103	29.3	120	16.1	4	20.3	22	3.0
	83	10.8	43	3.6	6	6.9	21	1.2					20	8.1
213753	236	30.4	202	2.5	87	38.5	21	44.8	90	15.5	14	17.6	146	22.7
	18	3.0	48	7.2									86	12.3
215717	53	27.7	2	27.2	15	9.9	25	6.4	31	3.0	1	2.1	29	4.9
220412	55	32.0	24	25.3	22	20.7	26	2.2	55	5.8	29	8.7	55	5.4
	31	2.4	50	3.0	44	9.6	43	9.9	11	0.0	3	3.6	48	9.0
222439	199	17.9	111	24.2	88	6.8	132	14.8	33	24.8	141	21.6	106	12.6
	145	9.8	188	17.2	32	1.8	104	6.7	87	18.0	58	11.4	21	1.9
	8	1.7	71	0.6	21	1.1							66	5.5
223841	67	1.6	101	2.8	75	13.6	35	1.0	124	11.7	22	3.3	13	6.9
	43	4.8	1	15.5	23	12.2	79	9.8	24	3.3	34	11.9	85	5.3
231425	17	13.1	28	50.4	238	53.8	196	3.7	65	27.9	84	19.4	54	27.7
	0	10.1	19	22.3									4	7.4
235209	130	6.3	74	27.8	55	8.1	88	14.3	92	19.2	30	26.7	2	9.3
	2	3.9	7	2.1	28	2.1							14	6.9

An examination of Table I and of the Provisional Catalogue given in Volume XLVIII shows how much useful work remains to be done on these variables. Apparently, no observations are now being made of many of these stars, although the photographs taken here and at Arequipa probably furnish the means of following them all. There is danger, however, that hereafter, from lack of visual observations at the present time, many important facts cannot be established. It is hoped that astronomers will select and publish sequences for the variables for which this has not been done, and will undertake systematic observations of them. If the variables are observed photometrically but few comparison stars will be needed, and these should be included in the final sequence when it is selected. Photometric measures will be made here so far as possible, in order that the observations may be reduced to the same photometric scale as that employed for the other variables. It is the policy of this Observatory to aid others in rendering their work homogeneous, and the initiative has been taken in the present case only since otherwise it appeared probable that this work would not have been undertaken.

EDWARD C. PICKERING.

JANUARY 1, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 75.

VARIABILITY OF IRIS (7).

A SERIES of measurements of the light of the planet Iris (7) has been made by Professor Wendell with the polarizing photometer, with sliding achromatic prisms, attached to the 15-inch equatorial telescope of the Harvard College Observatory. A variation like that of the planet Eros has been established, having a period of about $0^d.259 = 6^h 13^m$. The range is only two or three tenths of a magnitude, and the variation would be uncertain but for the very small accidental errors which occur in observations made in this way. See Circulars Nos. 23, 25, 30, and 41.

The results of the measures made by Professor Wendell are given in Table I. The Julian Day and fraction following Greenwich Mean Noon, omitting the three left hand figures, 241, is given in the first column. The designation of the comparison star is given in the second column. The observed difference in magnitude between Iris and the comparison star is given in the third column, a positive sign indicating that the star was brighter than Iris. The fourth column gives the phase computed by the formula $2.416,470^d.000 + 0^d.259 E$. The fifth column gives the amount that Iris is fainter than its assumed maximum magnitude. This quantity was found by plotting the times and observed differences in magnitude on each night, and by inspection assuming the maximum magnitude. The latter was then subtracted from the observed magnitude, and a curve constructed from these differences and the corresponding phases. Owing to errors in the assumed maximum magnitudes, the points on some nights were above and on others below the curve. The mean value of the deviations from the curve for each night was therefore subtracted from these differences and gives the quantity contained in the fifth column. Negative signs are indicated by Italics. This process was necessary, since different stars were used on different nights, and we had no means of knowing their true magnitudes. The sixth column gives the residual found by subtracting the magnitude as given by a smooth curve from that contained in the fifth column. The average value of these 46 residuals is only ± 0.022 .

TABLE 1.

OBSERVATIONS OF IRIS (7).

J. D.	DM.	Diff.	Phase.	M.	O — C.	J. D.	DM.	Diff.	Phase.	M.	O — C.
6475.606	+18 1576	−0.79	0.167	0.22	0.03	6487.540	+18 1495	−1.68	0.187	0.10	0.00
“ .612	“ “	−0.86	0.173	0.15	0.02	“ .546	“ “	−1.72	0.193	0.06	0.00
“ .658	“ “	−1.01	0.219	0.00	0.01	“ .568	“ “	−1.76	0.215	0.02	0.01
“ .665	“ “	−1.02	0.226	0.01	0.02	“ .576	“ “	−1.76	0.223	0.02	0.01
6477.645	+18 1533	−0.96	0.134	0.06	0.02	“ .599	“ “	−1.73	0.246	0.05	0.00
“ .651	“ “	−0.90	0.140	0.12	0.02	“ .606	“ “	−1.75	0.253	0.03	0.04
“ .662	“ “	−0.86	0.151	0.16	0.00	“ .627	“ “	−1.64	0.015	0.14	0.04
6479.603	+18 1538	+0.12	0.020	0.21	0.02	“ .636	“ “	−1.59	0.024	0.19	0.02
“ .611	“ “	+0.11	0.028	0.20	0.01	“ .656	“ “	−1.68	0.044	0.10	0.03
“ .656	“ “	−0.02	0.073	0.07	0.04	“ .664	“ “	−1.71	0.052	0.07	0.01
“ .664	“ “	−0.07	0.081	0.02	0.00	6495.567	+18 1419	−1.00	0.185	“	“
6480.552	“ “	−0.08	0.192	0.05	0.02	“ .574	“ “	−1.02	0.192	“	“
“ .558	“ “	−0.13	0.198	0.00	0.04	6498.543	+18 1391	−1.99	0.053	0.08	0.00
“ .586	“ “	−0.07	0.226	0.06	0.05	“ .551	“ “	−2.04	0.061	0.03	0.02
“ .612	“ “	−0.07	0.252	0.06	0.01	6499.524	“ “	−1.82	0.257	0.21	0.10
“ .621	“ “	−0.04	0.002	0.09	0.03	“ .530	“ “	−1.82	0.004	0.21	0.07
6485.565	+18 1496	−1.66	0.025	0.25	0.04	“ .546	“ “	−1.80	0.020	0.23	0.03
“ .570	“ “	−1.68	0.030	0.23	0.02	“ .552	“ “	−1.82	0.026	0.21	0.00
“ .601	“ “	−1.83	0.061	0.08	0.00	“ .578	“ “	−1.96	0.052	0.07	0.01
“ .606	“ “	−1.91	0.066	0.00	0.04	“ .585	“ “	−1.97	0.059	0.06	0.00
“ .624	“ “	−1.88	0.084	0.03	0.01	“ .603	“ “	−2.01	0.077	0.02	0.00
“ .631	“ “	−1.90	0.091	0.01	0.01	“ .610	“ “	−2.08	0.084	0.05	0.07
“ .651	“ “	−1.86	0.111	0.05	0.00	“ .630	“ “	−2.03	0.104	0.00	0.03
“ .660	“ “	−1.83	0.120	0.08	0.02	“ .660	“ “	−1.96	0.134	0.07	0.03

TABLE II. — LIGHT CURVE.

Ph.	M.	Ph.	M.	Diff.
0.00	0.12	0.13	0.09	0.03
0.01	0.16	0.14	0.12	0.04
0.02	0.19	0.15	0.17	0.02
0.03	0.21	0.16	0.19	0.02
0.04	0.17	0.17	0.18	0.01
0.05	0.10	0.18	0.14	0.04
0.06	0.05	0.19	0.09	0.04
0.07	0.03	0.20	0.06	0.03
0.08	0.02	0.21	0.02	0.00
0.09	0.02	0.22	0.01	0.01
0.10	0.03	0.23	0.02	0.01
0.11	0.04	0.24	0.03	0.01
0.12	0.06	0.25	0.03	0.03

The coordinates of the light curve are given in Table II. The phases are given in the first and third columns, the corresponding magnitudes in the second and fourth columns. The differences found by subtracting the numbers in the fourth column from those in the second are given in the fifth column. It will be seen therefore that there are two maxima and two minima, which are so nearly equal that it is as yet impossible to say whether the differences are real or due to small systematic errors. In the latter case, the period should be divided by two, and become $0^d.1295 = 3^h 6^m$.

It will be seen that the variation closely resembles that of Eros, and that the conditions discussed in Circular No. 58, apply to Iris also. The latter asteroid is bright enough to be readily observed during a

large part of the time, but unfortunately the change of light is now so small that it can be determined only by observations in which the accidental errors are extremely small. In fact, the observations of Iris made at Potsdam in 1884 (Publicationen, VIII, 294) fail to show this variation, either because the range was then too small, the period was then different, or the errors of observation rendered the variation imperceptible. The average of the residuals on the twenty-six nights of observation was ± 0.073 , or about the same as that for the other asteroids. A change in the period seems improbable.

The observations contained in Table III were made on January 25, 1904, after the above discussion was completed. Iris was compared with $+17^\circ 1404$, and the Julian Day and fraction, difference in magnitude, and phase, are given in the successive columns. It will be seen by plotting these observations, that they fall almost exactly upon a smooth curve and that the phase of maximum, $0^d.085$, agrees very nearly with that derived from the previous observations. A change, however, appears to have taken place in the range which now exceeds three tenths of a magnitude, or an increase of about one half in a few days. This change is confirmed by the last ten residuals in the last column of Table I, which indicate that the increase in range occurred between J. D. 6487 and J. D. 6499. The change in the range of Eros in the spring of 1901 was also much more rapid than might have been expected from geometrical considerations. The range on March 12, 1901, was found to be about 1.0, on April 12, 1901, 0.4, and on May 6 and 7, 1901, 0.0, magnitudes.

Evidently, this object should be watched carefully. It is now favorably situated, as it is approaching its second stationary point, and is of about the eighth magnitude. Iris can be conveniently compared photometrically with the stars $+17^\circ 1339$, $+17^\circ 1355$, $+17^\circ 1364$, and $+17^\circ 1391$, during the next few weeks, and it is hoped that observers elsewhere will connect their observations with these stars and with the comparison stars used in Tables I and III, so that all may be reduced to one system. Measures of the absolute magnitudes of these stars will be undertaken here. It will be noticed that observations on each night should extend over at least three hours. In that case, a maximum and minimum will always be included, so that the absolute magnitudes of the comparison stars will be of less importance.

TABLE III.
LATER OBSERVATIONS.

J. D.	Diff.	Ph.
6505.539	-0.52	0.056
" .546	-0.56	0.063
" .562	-0.59	0.079
" .569	-0.60	0.086
" .585	-0.58	0.102
" .592	-0.56	0.109
" .610	-0.44	0.127
" .619	-0.37	0.136
" .636	-0.28	0.153
" .645	-0.34	0.162
" .656	-0.38	0.173
" .662	-0.46	0.179

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 76.

STARS HAVING PECULIAR SPECTRA.

AN examination of the photographs of the Henry Draper Memorial has led to the discovery by Mrs. Fleming of a number of variable stars and objects having peculiar spectra, in addition to those previously published. A list of these has been compiled by Mrs. Fleming, and is given in the table, together with a number of other variables found as described in the remarks following the table. The constellation and catalogue designation are given in the first two columns. The approximate right ascension and declination for 1900, and the catalogue magnitude, are given in the third, fourth, and fifth columns. The class of spectrum, a brief description of the object, and the name of the discoverer, are given in the sixth,

Constellation.	Designation.	R. A. 1900.	Dec. 1900.	Magn.	Spectrum.	Description.	Discoverer.
		<i>h. m.</i>	<i>° ′</i>				
Taurus	....	5 46.9	+15 57	..	...	Variable.	W. P. Fleming.
Auriga	+42° 1571	6 27.6	+42 34	9.3	N.	Variable.	W. P. Fleming.
Canis Minor	....	7 42.8	+ 5 44	..	...	Variable.	L. D. Wells.
Vela	-46° 3951	8 11.7	-46 10	7.1	B 3 A	H β Bright.	A. J. Cannon.
Vela	-48° 4658	9 20.4	-48 26	10.0	Md.	Variable.	W. P. Fleming.
Carina	....	9 35.9	-59 38	..	Br. lines.	Gaseous Nebula.	W. P. Fleming.
Carina	-57° 2781	10 8.3	-57 33	6.7	B 3 A	H β Bright.	W. P. Fleming.
Carina	....	10 32.8	-70 12	..	Md.	Variable.	W. P. Fleming.
Vela	-47° 6614	11 8.6	-47 40	9.9	Pec.	Dark bands.	W. P. Fleming.
Ursa Major	+58° 1346	11 51.3	+58 25	7.5	Md.	Variable.	E. S. King.
Crux	....	12 50.7	-57 21	..	Pec.	Variable.	W. P. Fleming.
Centaurus	-56° 5650	13 7.6	-56 26	9.4	...	Variable.	S. E. Breslin.
Virgo	-18° 3640	13 31.0	-19 5	9.0	...	Variable.	W. P. Fleming.
Ara	-45° 11383	17 11.6	-45 52	10.0	N.	Variable.	L. D. Wells.
Lyra	+28° 3055	18 37.6	+28 43	9.3	Mc.	Variable.	W. P. Fleming.
Telescopium	-50° 12918	20 12.9	-50 8	10.0	N.	Variable.	L. D. Wells.
Capricornus	-16° 5558	20 13.3	-16 10	8.0	Mc.	Variable.	W. P. Fleming.
Cygnus	+40° 4393	20 58.9	+40 54	8.4	...	Variable.	J. A. Dunne.
Indus	-54° 9810	21 3.1	-54 7	10.0	Pec.	Dark bands.	W. P. Fleming.
Cepheus	....	22 12.9	+55 7	..	Br. lines.	Type V.	W. P. Fleming.
Lacerta	....	22 19.9	+50 28	..	Br. lines.	Gaseous Nebula.	W. P. Fleming.
Pegasus	....	22 59.2	+14 45	..	...	Variable.	E. C. Pickering.

seventh, and eighth columns. The designations for stars north of declination -23° are taken from the Bonn Durchmusterung, for stars between declinations -23° and -52° the Cordoba Durchmusterung is used, and for stars south of declination -52° the Cape Photographic Durchmusterung is used. Each of these variables has been confirmed independently by a second observer.

REMARKS.

- | | |
|---|--|
| <p><i>h. m.</i></p> <p>5 46.9. Found by comparison of photographic charts while identifying Anderson's variable star, Z Tauri. Measures of one hundred and fifty-seven plates, taken between December 16, 1885 and April 24, 1903, show a variation in magnitude from 11.7 to 14.5.</p> <p>7 42.8. An examination of twenty-two plates, taken between February 22, 1886, and February 19, 1903, shows a variation of about half a magnitude in the preceding and northern of two faint adjacent and nearly equal stars. This deviation although small seems to be real, as sometimes one and sometimes the other is the brighter of the two stars. Their distance apart is about $25''$.</p> <p>8 11.7. Miss Cannon finds that the line Hβ is bright in the spectrum of this star, and suspects that this line is variable.</p> <p>9 20.4. Spectrum Type III, having also the lines Hδ and Hγ bright.</p> <p>9 35.9. A very faint gaseous nebula.</p> <p>10 32.8. Spectrum Type III, having also the lines Hδ and Hγ bright.</p> <p>11 8.6. In the spectrum of this star a strong dark band extends from about λ 465 to 471. This band seems to have the same wave length as the strong bright band in H. P. 1311, and similar spectra of Type V.</p> <p>11 51.3. Found from peculiarity of its spectrum which is of Type III having also the lines Hδ and Hγ bright. An examination of twenty-two plates, taken between November 9, 1897 and March 13, 1904, shows a variation of at least 1.5 magnitudes.</p> <p>12 50.7. In the spectrum of this star a strong dark band extends from about λ 465 to 471, and it closely resembles the spectrum of $-47^\circ 6614$, except that the lines Hγ</p> | <p><i>h. m.</i></p> <p>and Hβ are bright. No other star has, so far, been found showing these peculiarities in its spectrum.</p> <p>13 7.6. Found from photographic charts, while measuring magnitudes of $-56^\circ 5632$. It was originally the comparison star <i>n</i> for this variable.</p> <p>13 31.0. Found by comparison of photographic charts while looking for asteroid found on Plate A 3078, taken on June 8, 1898.</p> <p>17 11.6. An examination of nine plates, taken between June 24, 1893 and June 20, 1901, shows a variation of about 1.0 magnitude.</p> <p>18 37.6. An examination of eighteen photographic charts, taken between July 21, 1892 and May 1, 1903, shows a variation of about 0.8 magnitude.</p> <p>20 12.9. An examination of ten plates, taken between August 25, 1889 and July 30, 1902, shows a variation of about 0.7 magnitude.</p> <p>20 58.9. Found in 1901, by Mr. Dunne, from observations with the meridian circle. An examination of nineteen plates, taken between November 6, 1889 and July 12, 1900, shows a variation of about 1.0 magnitude.</p> <p>21 3.1. The spectrum of this star is similar to that of $-47^\circ 6614$, magn. 9.9, mentioned above, and Z. C. 18δ 1935, magn. 9. These three are the only stars, so far known, which have this spectrum.</p> <p>22 19.9. A spectrum plate, taken with the 8-inch Draper Telescope on December 18, 1903, shows the spectrum of this faint gaseous nebula superposed on that of $+50^\circ 3007$, magnitude 9.4, which is of Class A.</p> <p>22 59.2. Found from comparison of chart plates. Measures of sixty-nine plates, taken between November 23, 1889 and January 19, 1901, show a variation in magnitude from 8.8 to 12.2.</p> |
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In a photograph taken with the 8-inch Bache Telescope on July 15, 1898, the variable star RS Ophiuchi has a spectrum of the third type in which the lines H ζ , H ϵ , H δ , H γ , and H β are bright, the estimated relative intensities of these lines being about 2, 1, 5, 10, and 20, respectively. Two bright lines, intensities 7 and 14, are also present. They appear to coincide with the bright lines in γ Velorum, whose wavelengths are 4656 and 4691. No other variable star having this type of spectrum has hitherto been found.

EDWARD C. PICKERING.

MARCH 21, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 77.

FIRST SUPPLEMENT TO CATALOGUE OF VARIABLE STARS.

A Provisional Catalogue of Variable Stars, based on material published before the end of 1902, was prepared by Miss Cannon, and published as No. III of Volume XLVIII of the Annals of this Observatory. A supplementary list of stars announced as variable during the publication of the work was appended on page 122. The bibliography on which this work was based is kept up to date by Miss Cannon, and she has prepared a list of the variables required to make this work complete to the end of 1903. This list is given in the following table in the same form as the Provisional Catalogue.

Des.	Prov. Des.	Name.	DM.	R. A. 1900.	Dec. 1900.	Max.	Min.	Period.	Epoch.	Class.	Sp.	Date.	Discoverer.
				<i>h. m.</i>	<i>s. ° ' "</i>			<i>d.</i>					
001706	60.1903	— Piscium	43	0 17.2	+ 6 7	..	..	..	...	S	..	1903	Kosz
012288	18.1903	— Ursae Minoris	..	1 22.6	+ 88 46	..	..	..	...	S	..	1903	Jost
012233b	23.1903	— Sculptoris	..	22.6	- 33 25	9.8	11.0	..	...	S	..	1903	de Sitter
013238	11.1903	RU Andromedae	..	32.8	+ 38 10	9	13	265?	2415969	II	..	1903	Williams
021143b	62.1903	— Andromedae	462	2 11.4	+ 43 51	8.8	9.9	..	...	S	..	1903	Hagen
021281	15.1903	Z Cephei	..	12.8	+ 81 13	9.5	< 12.5	..	...	II	..	1903	L. Ceraski
022980	56.1903	RR Cephei	..	29.4	+ 80 42	9	< 13	390?	...	II	..	1903	L. Ceraski
043274	22.1903	X Camelopardali	..	4 32.6	+ 74 56	9	13	152	2416269	II	..	1903	L. Ceraski
052704	32.1903	— Orionis	..	5 27.0	- 4 31	14.0	< 15	..	...	..	..	1903	Wolf
052705	33.1903	— Orionis	..	27.2	- 5 7	11.3	15.0	..	...	..	..	1903	Wolf
052707a	34.1903	— Orionis	..	27.3	- 7 33	13.3	14.0	..	...	..	..	1903	Wolf
052707b	35.1903	— Orionis	..	27.8	- 7 39	13.6	< 14	..	...	..	..	1903	Wolf
052805	36.1903	— Orionis	..	28.6	- 5 16	13.8	15.0	..	...	..	..	1903	Wolf
052904a	37.1903	— Orionis	..	29.0	- 4 52	13.0	15.2	..	...	..	..	1903	Wolf
052906	38.1903	— Orionis	..	29.4	- 6 40	13.0	15.0	..	...	..	..	1903	Wolf
052904b	39.1903	— Orionis	..	29.9	- 4 44	12.5	14.0	..	...	..	..	1903	Wolf
053005c	40.1903	— Orionis	..	30.0	- 5 51	12.5	14.0	..	...	..	..	1903	Wolf
053005d	41.1903	— Orionis	..	30.3	- 5 50	12.0	14.5	..	...	..	..	1903	Wolf
053004	42.1903	— Orionis	..	30.3	- 4 50	12.7	< 14	..	...	..	..	1903	Wolf
053005e	43.1903	— Orionis	..	30.4	- 5 39	12.3	< 14	..	...	..	..	1903	Wolf
053006b	50.1903	— Orionis	..	30.7	- 6 49	12.5	< 14	..	...	S	..	1903	Wolf

Des.	Prov. Des.	Name.	D.M.	R. A. 1900.	Dec. 1900.	Max.	Min.	Period.	Epoch.	Class.	Sp.	Date.	Discoverer.
				<i>h. m.</i>	<i>° ' "</i>			<i>d.</i>					
053104	44.1903	- Orionis	..	5 31.0	- 4 51	12.8	<15	..	...	..	..	1903	Wolf
053106a	45.1903	- Orionis	..	31.0	- 6 55	12.5	15.0	..	...	..	..	1903	Wolf
053106b	46.1903	- Oriouis	..	31.2	- 6 46	12.6	<14	..	...	..	..	1903	Wolf
053203	51.1903	- Orionis	..	32.3	- 3 35	13.0	14.0	..	...	S	..	1903	Graff
053307	47.1903	- Orionis	..	33.6	- 7 19	13.5	15.0	..	...	..	..	1903	Wolf
053404	52.1903	- Oriouis	..	34.5	- 4 57	12.5	13.2	..	...	S	..	1903	Wolf
053506	53.1903	- Orionis	..	35.7	- 6 29	13.2	14.0	..	...	S	..	1903	Wolf
053608a	48.1903	- Orionis	..	36.0	- 8 9	13.0	15.0	..	...	..	..	1903	Wolf
053608b	54.1903	- Orionis	..	36.0	- 8 8	12.8	13.9	..	...	S	..	1903	Wolf
053604	49.1903	- Orionis	..	36.6	- 4 11	9.8	<15	..	...	..	..	1903	Wolf
054615c	..	- Tauri	..	46.8	+15 58	..	..	..	...	..	..	1903	Fleming
061919	7.1903	- Geminorum	1347	6 19.8	+19 35	..	..	..	...	S	..	1903	Graff
063730	12.1903	Nova Geminorum	..	37.8	+30 3	5.0	?	..	...	I	Pec.	1903	Turner
065530	14.1903	RS Geminorum	..	55.2	+30 40	9.5	11	115?	2416190	II	..	1903	L. Ceraski
070122b	9.1903	Z Geminorum	1579	7 1.6	+22 41	9.5	12	..	...	..	..	1903	Graff
071201	16.1903	RR Monocerotis	..	12.4	+ 1 17	9.3	<15	336?	2416378	II	..	1903	L. Ceraski
071531	13.1903	RR Geminorum	..	15.2	+31 4	10	11.5	0.3+	...	IV	..	1903	L. Ceraski
071725	24.1903	- Canis Majoris	4309	17.3	-25 16	8.7	10.2	..	...	S	..	1903	de Sitter
072776	21.1903	Y Camelopardali	286	27.6	+76 17	9.5	<11	3.3+	...	V	..	1903	L. Ceraski
082139	25.1903	- Puppis	..	8 21.8	-39 43	..	..	..	...	S	..	1903	de Sitter
130756	..	- Centauri	..	13 7.6	-56 26	..	..	..	...	..	..	1903	Breslin
133273	57.1903	T Ursae Minoris	..	32.6	+73 56	9	<13	323?	...	II	..	1903	L. Ceraski
154748	29.1903	ST Herculis	2334	15 47.8	+48 47	7.4	8.1	R	...	Me	..	1903	M. and K.
162546	26.1903	- Normae	10821	16 25.6	-46 43	8.8	10.0	..	...	S	..	1903	de Sitter
174422	31.1903	SU Herculis	..	17 44.7	+22 34	10	<12	..	...	..	..	1903	L. Ceraski
174824	27.1903	- Sagittarii	13604	48.2	-24 49	9.3	<10.6	..	...	..	..	1903	de Sitter
175724	30.1903	- Sagittarii	..	17 57.2	-24 30	11.2	13.8	..	...	..	..	1903	Wolf
183728	..	- Lyrae	3055	18 37.6	+28 43	..	..	..	...	..	Me	1903	Fleming
183932	19.1903	RZ Lyrae	..	39.9	+32 42	9.9	11.2	0.5+	2416266	IV	..	1903	Williams
184134	17.1903	RY Lyrae	..	41.2	+34 34	10	12	348?	2415316	II	..	1903	Williams
185032	10.1903	RX Lyrae	..	50.4	+32 42	11	<15	250	2416233	II	..	1903	Seeliger
191046	63.1903	- Lyrae	..	19 10.4	+46 49	9.2	10.3	..	...	..	..	1903	Anderson
192710	64.1903	- Aquilae	..	27.8	+10 19	11.5	15	..	...	..	..	1903	Wolf
193007	65.1903	- Aquilae	..	30.4	+ 7 2	12.5	14	..	...	..	..	1903	Wolf
193312	66.1903	- Aquilae	..	33.2	+12 34	13	<14	..	...	..	..	1903	Wolf
193412	67.1903	- Aquilae	..	34.0	+12 2	11.0	14.5	..	...	..	..	1903	Wolf
193411	68.1903	- Aquilae	..	34.3	+11 43	13	<14	..	...	..	..	1903	Wolf
193607	69.1903	- Aquilae	..	36.4	+ 7 11	11.5	14	..	...	..	..	1903	Wolf
193813	70.1903	- Aquilae	..	38.1	+13 20	12.0	14.5	..	...	..	..	1903	Wolf
194008	71.1903	- Aquilae	..	40.4	+ 8 12	11.0	<15	..	...	..	..	1903	Wolf
194110a	72.1903	- Aquilae	..	41.8	+10 32	13.5	<15	..	...	..	..	1903	Wolf
194110b	73.1903	- Aquilae	..	41.9	+10 13	14	<15	..	...	..	..	1903	Wolf
194207	74.1903	- Aquilae	..	42.4	+ 7 23	11.5	13.5	..	...	..	..	1903	Wolf
194212	75.1903	- Aquilae	..	42.5	+12 14	11.5	<15	..	...	..	..	1903	Wolf
194209	76.1903	- Aquilae	..	42.8	+ 9 42	12.0	<15	..	...	..	..	1903	Wolf

Des.	Prov. Des.	Name.	DM.	R. A. 1900.	Dec. 1900.	Max.	Min.	Period.	Epoch.	Class.	Sp.	Date.	Discoverer.
				<i>h. m. °</i>	<i>°</i>			<i>d.</i>					
194311	77.1903	-Aquilae	..	19 43.7	+11 17	10.0	12.0	..	...	..	..	1903	Wolf
194412	78.1903	-Aquilae	..	44.6	+12 7	11.0	13	..	...	..	..	1903	Wolf
194612a	79.1903	-Aquilae	..	46.0	+12 34	11.5	14	..	...	..	..	1903	Wolf
194612b	80.1903	-Aquilae	..	46.3	+12 58	11	<14	..	...	..	..	1903	Wolf
194809	81.1903	-Aquilae	..	48.7	+9 7	12	14	..	...	..	..	1903	Wolf
149910	82.1903	-Aquilae	..	49.0	+10 44	12	13	..	...	..	..	1903	Wolf
194909	83.1903	-Aquilae	..	49.1	+9 24	11	13	..	...	..	..	1903	Wolf
194907a	84.1903	-Aquilae	..	49.4	+7 21	11.5	12.5	..	...	..	..	1903	Wolf
194907b	85.1903	-Aquilae	..	49.5	+7 45	13	<14	..	...	..	..	1903	Wolf
201134	55.1903	VW Cygni	3938	20 11.4	+34 12	9.8	11.8	8.4 +	2416348	V	..	1903	Williams
201316	..	-Capricorni	..	13.3	-16 10	..	..	..	...	..	Mc	1903	Fleming
201437b	59.1903	-Cygni	3876	14.8	+37 8	..	..	..	...	II	N	1903	Wolf
205339	58.1903	VX Cygni	4379	53.6	+39 48	9	10	20	2416364	IV?	..	1903	Williams
210039	61.1903	-Cygni	4423	21 0.4	+39 35	8.8	9.5	7.8 +	2416370	IV	..	1903	Williams
231110	..	-Pegasi	5191	23 11.8	+10 4	..	..	..	...	..	Mc	1903	Fleming
235425	28.1903	-Ceti	..	54.5	-25 0	9.7	<11.5	..	...	S	..	1903	de Sitter

REMARKS.

001706. Variability suspected because the star is now much fainter than 9.5, which is the magnitude given in the Bonn Durchmusterung.

012288. This is the companion to Polaris. See Astron. Nach. **162**, 189.

061919. This star is contained in the Durchmusterung, but was missed by Graff. An investigation, by Deichmüller and Kreutz, of the original observations made in forming the Durchmusterung proved that it is doubtful whether this star ever existed.

070122b. This star is contained in the Durchmusterung, but was missed by Hagen when preparing the chart of R Geminorum for the Atlas of Variable Stars. It was observed at Bonn on December 3, 1855, as magnitude 9.5, and by Kobold on March 22, 1895, as magnitude 9.8. It appears in the Catalog der Astronomischen Gesellschaft X, 186, as 2788a. A photograph taken at this Observatory on April 5, 1895, 14 days after the

observation by Kobold, fails to show any object brighter than magnitude 11 at or near the position of the Durchmusterung star.

071531. Period 9^h.5. Ceraski.

071725. C. P. D. -25° 2242.

072776. Period 3^d.3056. Blajko.

082139. C. P. D. -39° 2378 and 2380. It appears to be uncertain which of these stars is variable.

154748. "Period appears to be several months." Müller and Kempf.

162546. C. P. D. -46° 8056.

174824. C. P. D. -24° 6006.

175724. In nebula Messier 8. N. G. C. 6523.

183932. Times of maximum, J. D. 2416266.5768 + 0^d.511284 E.

201134. Times of maximum, J. D. 2416348.5985 + 8^d.4326 E.

210039. Times of maximum, J. D. 2416370.88 + 7^d.857 E.

The following corrections and additions should be made to Table I, "Provisional Catalogue of Variable Stars," on page 96 of Volume XLVIII.

001032. C. DM. -32° 69.

004533. Period, 340 days. Epoch, J. D. 2416164. Hartwig. Class II.

005381. For period 2^d.5 +, read 2^d.4 +.

021143. Period 395 days. Epoch, J. D. 2415790. Maximum magnitude, 6.5.

022741. Period 270 days. Epoch, J. D. 2415806. Innes. Class II. Discoverer, (Cape).

032528. Period 95 days. Class II. Discoverer, (Cape).

040725. The epoch given is for minimum. For maximum it is J. D. 2410290.

054629. Hartwig's period, given in the Provisional Catalogue,

- is too long. The maximum of 1901 occurred on February 27, according to the Harvard photographic observations, whereas the elements gave a date 78 days later. The maximum due on February 9, 1904, according to the elements of the catalogue, must have occurred much earlier. According to visual observations made at this Observatory, the variable was about the ninth magnitude on December 14, 1903, and was invisible and fainter than the tenth magnitude on January 25, 1904. Period, 323 days. Epoch, J.D. 2410277.
055686. Roberts' elements, given in the catalogue, are not confirmed by the Harvard photographic observations. The period is much longer than 330 days. The formula as determined from 10 photographic maxima is J.D. 2410356 + 408 E.
060450. Period, 161 days. Graff. Epoch for minima, J.D. 2416029.
073173. Period, 393.5 days. Epoch, J.D. 2415042. Innes.
073520. Y Geminorum.
082476. Period, 335 days. Epoch, J.D. 2410238.
083850. Max. 10.1. Min. <13.1. Period, 251 days. Epoch, J.D. 2412040. Pickering.
091868. Max. 8.5. Min. <11.5. Period, 322 days. Epoch, J.D. 2410259. Class II.
094953. Period, 407 days. Epoch, J.D. 2415050. Innes.
123834. Roberts' period of 216.8 days appears to be too short. According to the Harvard photographic observations, the period is 220 days. Epoch, J.D. 2410211.
140113. Period, 280 days. Epoch, J.D. 2414378.
153378. Spectrum, Md.
155829. Spectrum, Ma.
164844. Period, 323 days. Epoch, J.D. 2410123.
174135. This star is C. P. D. -35° 7270, and is not in the C. D.M.
175111. RT Ophiuchi. Period, 400 days. Epoch, J.D. 2415354. Hartwig. Class II.
175829. For Spectrum G 5 K, read F 5 G.
202539. Spectrum, Ma.
202817. Z Delphini. Period, 291 days. Epoch, J.D. 2416137. Hartwig.
203611. Y Delphini. Max. 9. Min. <13. Period very long, 17 to 19 months. Hartwig.
215934. RT Pegasi. Min. <13. Period, 242 days. Epoch, J.D. 2416318. Hartwig.
220412. Spectrum, Mb.
235048. R S Andromedae.

The following corrections and additions should be made to Table IV, "Supplementary List," on page 122 of Volume XLVIII.

054615. R S Tauri. The designation should be 054615b, and the designation of Z Tauri should be 054615a. R S Tauri is probably not Class II. Very little variation found by Miss Leavitt from examination of the Harvard photographs.
055353. Z Aurigae.
092448. Read 092048. For right ascension, read 9^h 20^m.4.
093178. Y Draconis. Period, 336 days. Hartwig.
093656. W Ursae Majoris.
103270. Period, 272 days. Epoch, J.D. 2410126.
113972. Z Draconis. A visual minimum, magnitude 13.6, was observed by Reed at the Halsted Observatory.
161138. W Coronae Borealis. The corrected position of this star for 1900 is R.A. = 16^h 11^m.8, Dec. = + 38° 3'.
184243. RW Lyrae. Period long. Williams. Period about 17 months. Hartwig.
201520. V Sagittae. Period irregular.
210245. V V Cygni.

In the remarks following Table I, beginning on page 110, the numbers of observations by L. Campbell of 045443, 060822, and 214058, are incorrectly described. It should have been stated that he obtained 26 observations extending over 400 nights, 46 observations extending over 200 nights, and 19 observations extending over 500 nights, of these three stars respectively. On the sixth line of page 113, for C.D.M., read DM.

EDWARD C. PICKERING.

MARCH 22, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 78.

VARIABLE STARS IN THE NEBULA OF ORION.

THE Great Nebula of Orion has been the subject of careful study by astronomers for many years. Volume V of the Annals of the Harvard Observatory contains an elaborate discussion of this nebula, by Professor Bond, including a comparison of the material previously collected. Many stars in it have been announced as variable, but strangely enough the changes in only one of them, T Orionis, have been generally admitted. In 1901, and again in 1903, Professor Wolf of Heidelberg compared several of his photographs by means of stereo-comparators and announced a number of variables in this part of the sky. They do not appear to have been confirmed by other observers, and final designations have not yet been assigned to them. The faintness of many of these stars even at maximum renders it probable that comparatively few photographs exist on which they can be followed. A grant made by the Carnegie Institution for 1903, permitted a large amount of work of this kind to be undertaken here, and furnished a corps of eight observers for the study of the Harvard photographs. The failure to continue this grant for 1904 rendered it necessary to disband this corps, and since December, 1903, similar work has been carried on, at the expense of the Observatory, by only one observer, Miss Henrietta S. Leavitt. A number of photographs of the Nebula of Orion, having long exposures, are contained in the Harvard collection, and a careful examination of them has been made by Miss Leavitt. Besides confirming sixteen of Wolf's variables, she has found many new ones, which renders it probable that nebulae as well as clusters may furnish fruitful fields for the discovery of such objects. Three plates taken with the 13-inch Boyden Telescope were examined, the first made on September 15, 1893, exposure 180^m, the second on September 17 and 18, 1893, exposure 480^m, and the third on December 5, 1893, exposure 151^m. Plates taken with the 24-inch Bruce Telescope, on January 8, 1894, exposure 60^m, January 25, 1894, exposure 60^m, January 27, 1895, exposure 180^m, October 6, 1896, exposure 180^m, November 9, 1896, exposure 123^m, November 10, 1896, exposure 265^m,

December 17, 1898, exposure 60^m , December 3, 1901, exposure 60^m , and December 4, 1901, exposure 420^m , were also used. For stars which, on plates having long exposures, are deeply involved in nebulosity, an examination was also made of plates taken with the 13-inch Boyden telescope on September 12, 1893, exposure 10^m , and on March 13, 1896, exposure 10^m , and of plates taken with the 24-inch Bruce Telescope on November 30, 1893, exposure 61^m , December 27, 1893, exposure 60^m , January 1, 1894, exposure 11^m , January 1, 1894, exposure 60^m , October 29, 1897, exposure 10^m , and December 8, 1898, exposure 10^m . Some excellent photographs taken with the 8-inch Bache Telescope in 1888 (*Annals* XVIII, 114) can be used only for the brighter variables. So far as possible, the map and catalogue of Bond (*Annals* V) were used to locate these stars, and their positions were derived by adding the co-ordinates given by Bond to those of θ^1 Orionis, whose position for 1900 is assumed to be R.A. = $5^h 30^m 21^s.3$, Dec. = $-5^\circ 27'.3$. Estimates were made of the positions of stars not in this catalogue, and are given to seconds of time in right ascension, and to tenths of a minute of arc in declination.

A provisional scale of magnitudes was used which is fairly comparable with that of Wolf. On this scale, the faintest stars seen on Plate 26 of Roberts' Photographs of Stars, Star Clusters and Nebulae, have the magnitude 14.8. The original negative was taken with his 20-inch reflector on January 15, 1896, and had an exposure of 90 minutes. The faintest stars shown in Plate XXIII of Volume VIII of the Decennial Publications of the University of Chicago have the magnitude 15.5. The original negative was taken with the 24-inch reflector on October 19, 1901, and had an exposure of 60 minutes.

A list of the stars certainly variable is given in Table I. Those found by Wolf have been confirmed by Miss Leavitt. Those found by Miss Leavitt have been examined by Mrs. Fleming, on several plates, and the variability in each case confirmed. Although the changes in some of these stars are small, they seem to be real since, owing to their faintness, good comparison stars can be found near them. A number for reference, the provisional designation given to Wolf's stars in the *Astron. Nach.* 163, 161, the number in the catalogue of Bond, the right ascension for 1900, and the declination for 1900, are given in the first five columns. The brightest and faintest magnitudes on the Harvard and Heidelberg photographs are given in the next four columns.

TABLE I.
STARS CERTAINLY VARIABLE.

No.	Designation.	Bond No.	R. A. 1900.			Dec. 1900.		Harvard.		Heidelberg.	
			h.	m.	s.	°	'	Br.	Ft.	Br.	Ft.
1	..	..	5	27	53.	-5	44.0	14.1	<15.5	..	..
2	..	..		28	27.	-5	26.1	14.5	<15.1	..	..
3	36.1903	..		28	37.	-5	16.1	14.4	14.9	13.8	15.0
4	..	..		28	37.	-4	47.6	14.0	15.0	..	..
5	..	173		28	37.0	-4	48.2	13.9	14.6	..	..
6	..	..		28	40.	-5	5.7	13.3	14.6	..	..
7	..	..		28	47.	-6	22.8	12.5	<15.5	..	..
8	..	..		28	54.	-6	44.3	13.2	15.5	..	..
9	..	..		28	59.	-5	45.8	13.2	14.1	..	..
10	37.1903	..		29	0.	-4	52.0	13.8	15.2	13.0	15.2
11	..	..		29	5.	-6	40.3	13.7	<15.5	..	..
12	..	276		29	8.7	-5	41.1	12.9	14.0	..	..
13	..	288		29	12.2	-5	17.8	12.9	14.2	..	..
14	..	..		29	15.	-4	54.1	14.5	15.2	..	..
15	..	..		29	21.	-5	8.6	14.3	<15.0	..	..
16	38.1903	..		29	24.	-6	40.0	11.4	14.1	13.0	15.0
17	..	..		29	29.	-5	35.0	13.5	14.8	..	..
18	..	..		29	31.	-4	49.5	14.9	15.5	..	..
19	..	417		29	42.8	-6	9.6	13.4	14.5	..	..
20	..	419		29	43.0	-5	39.0	14.1	14.6	..	..
21	..	435		29	46.0	-5	26.8	12.1	12.7	..	..
22	..	..		29	47.	-5	50.1	14.2	15.5	..	..
23	..	..		29	49.	-5	14.8	14.2	15.5	..	..
24	..	481		29	54.8	-6	2.0	11.8	12.8	..	..
25	39.1903	484		29	55.1	-4	44.2	14.0	14.6	12.5	14.0
26	40.1903	509		30	1.6	-5	50.6	13.2	13.9	12.5	14.0
27	..	511		30	2.1	-5	45.7	13.4	14.0	..	..
28	..	..		30	2.5	-6	27.9	13.1	14.0	..	..
29	..	520		30	4.3	-5	58.6	14.1	14.9	..	..
30	..	..		30	5.	-4	54.8	12.7	13.1	..	..
31	..	..		30	12.	-5	40.3	12.9	14.7	..	..
32	..	561		30	12.2	-4	31.7	12.2	14.6	..	..
33	..	..		30	13.	-5	41.1	14.1	15.0	..	..
34	41.1903	582		30	16.3	-5	50.5	12.1	13.0	12.0	14.5
35	42.1903	596		30	18.2	-4	49.7	13.0	13.7	12.7	<14
36	..	606		30	19.5	-5	47.2	12.7	13.7	..	..
37	..	620		30	20.7	-5	43.2	12.7	13.1	..	..
38	..	..		30	21.	-5	56.1	13.8	14.6	..	..
39	..	..		30	24.	-4	57.8	14.2	14.9	..	..
40	..	668		30	25.5	-4	46.2	12.4	13.0	..	..
41	43.1903	680		30	26.8	-5	38.6	12.9	14.0	12.3	<14

No.	Designation.	Bond No.	R. A. 1900.			Dec. 1900.		Harvard.		Heidelberg.	
			<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>o</i>	<i>r</i>	Br.	Ft.	Br.	Ft.
42	..	695	30	30.1		-5	13.7	11.1	12.5	..	..
43	..	703	30	31.0		-5	15.0	11.8	13.2	..	..
44	..	709	30	31.5		-5	29.6	10.7	11.3	..	..
45	..	..	30	34.		-4	59.1	13.2	14.3	..	..
46	83.1901	756	30	40.0		-5	5.1	11.6	14.2	11.8	13.2
47	50.1903	758	30	40.1		-6	49.2	13.4	14.6	12.5	<14
48	..	759	30	40.3		-5	25.5	13.0	13.6	..	..
49	..	784	30	47.2		-5	32.1	10.3	11.0	..	..
50	..	788	30	47.3		-5	9.7	14.0	<15.2	..	..
51	..	..	30	52.		-5	5.1	14.4	15.0	..	..
52	..	817	30	54.0		-5	53.5	14.1	14.8	..	..
53	..	822	30	55.6		-5	32.4	..	..	..	..
54	44.1903	..	30	57.		-4	51.1	13.3	<15.0	12.8	<15
55	..	838	30	58.1		-5	8.0	12.3	13.3	..	..
56	..	..	31	0.		-6	25.5	14.1	14.7	..	..
57	45.1903	..	31	1.		-6	54.8	14.5	15.4	12.5	15.0
58	..	..	31	9.		-4	45.5	14.0	14.8	..	..
59	46.1903	877	31	9.2		-6	46.5	13.0	14.9	12.6	<14
60	..	885	31	13.8		-6	18.2	12.8	13.9	..	..
61	..	..	31	16.		-6	52.0	14.4	<15.4	..	..
62	..	..	31	18.		-6	33.3	13.7	<15.0	..	..
63	85.1901	908	31	21.4		-5	15.4	11.5	12.1	11.8	<14
64	..	..	31	28.		-6	21.5	13.0	14.5	..	..
65	..	951	31	42.7		-5	29.9	13.5	14.6	..	..
66	..	..	31	46.		-6	23.1	12.1	13.3	..	..
67	..	1009	32	8.8		-6	37.1	11.5	<14.8	..	..
68	..	..	33	3.		-7	1.2	13.7	14.4	..	..
69	86.1901	..	34	46.1		-3	28.6	13.5	14.4	11.7	13.0
70	..	..	35	13.		-6	18.9	12.2	13.2	..	..
71	49.1903	..	36	36.0		-4	11.3	10.5	<14.8	9.8	<15

REMARKS.

3. Although the observed range is small, the variation is very clearly marked.
- 4.5. The variation of these adjacent stars is marked.
6. Period apparently short.
12. Period apparently short.
13. Period apparently short.
18. This star, although faint, gives distinct images on the plates, and the variation is well defined.
20. The variation of this star, though small, is well shown by a comparison with three neighboring stars of about magnitude 14.5.
28. Bond 528 and Bond 537, the stars nearest this position, are wrongly charted on Bond's map. The position has, therefore, been determined independently.
30. The variation is obvious when different photographs are compared, but the strong nebulosity in the region of this star makes measurements of the magnitudes difficult.
37. The variation is small but readily observed, as the variable is sometimes brighter and sometimes fainter than Bond 605 which precedes it 1^h 2, and is in the same declination.
44. This star was suspected of variability by Holden.
47. Wolf announced this star as probably variable.
49. This star was suspected of variability by Schmidt.
51. Although this is a faint variable it is easily observed. A star of about the fifteenth magnitude follows and is slightly south of it.

53. T Orionis. This star was not measured, but the variation is obvious, on the plates examined.
63. No marked variation was found in this star, which was observed with some difficulty.
64. This star is on Bond's chart, but not in the catalogue.
66. This star is on Bond's chart, but not in the catalogue.
68. This star precedes the position given by Wolf of 47.1903, 35' and is north of it 18'.
70. This star precedes the position given by Wolf of 53.1903, 26', and is north of it 10'.

A list of stars suspected of variability is given in Table II, in the same form as Table I omitting the last four columns. All of Wolf's stars may prove to be variable, but some are included in Table II since they have not yet been confirmed here.

TABLE II.
SUSPECTED VARIABLES.

No.	Designation.	Bond No.	R. A. 1900.			Dec. 1900.		No.	Designation.	Bond No.	R. A. 1900.			Dec. 1900.	
			<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>	<i>'</i>				<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>	<i>'</i>
1	80.1901	..	5	24	47.0	-8	5.2	19	..	..	5	30	37.	-4	52.8
2	32.1903	..	26	59.2	-4	31.4		20	..	801	30	51.0	-5	32.0	
3	33.1903	..	27	13.6	-5	7.1		21	..	833	30	57.3	-5	55.6	
4	34.1903	..	27	16.6	-7	32.8		22	..	..	30	59.	-5	30.3	
5	35.1903	..	27	54.0	-7	38.8		23	84.1901	..	31	0.4	-5	0.8	
6	..	216	28	50.5	-5	35.3		24	..	..	31	5.	-6	1.3	
7	81.1901	..	28	54.0	-4	42.8		25	..	..	31	37.	-5	20.8	
8	..	..	29	15.	-5	36.3		26	51.1903	..	32	18.4	-3	35.2	
9	..	361	29	29.1	-5	1.1		27	..	..	33	3.	-4	16.8	
10	..	492	29	56.8	-5	7.5		28	47.1903	..	33	38.4	-7	19.2	
11	..	..	30	0.	-6	33.5		29	52.1903	..	34	31.9	-4	57.4	
12	..	524	30	5.2	-5	27.0		30	87.1901	..	35	10.1	-5	24.4	
13	..	527	30	5.6	-5	48.5		31	53.1903	..	35	39.4	-6	29.0	
14	..	558	30	10.7	-5	29.3		32	48.1903	..	35	57.8	-8	8.5	
15	..	..	30	14.	-5	35.5		33	54.1903	..	35	57.9	-8	7.7	
16	..	..	30	17.	-5	34.5		34	88.1901	..	42	27.9	-6	14.8	
17	..	..	30	25.	-5	35.3		35	89.1901	..	43	16.1	-5	43.6	
18	82.1901	..	30	36.8	-6	7.1									

REMARKS.

- The region is on the extreme edge of the plates examined. No variation was detected in any star near the position announced.
- No star near this position was found to vary with certainty. A fourteenth magnitude star was suspected of being unduly faint on January 8, 1894, and on January 27, 1895.
- No variation could be found in any star near this position. Probably the variable remains faint during the greater part of the time, as it was seen bright on only one of the Heidelberg plates.
- A star of about the magnitude 14.5 in this position appears to fluctuate slightly in brightness, but no conclusive evidence of variation has been found.
- No variation was found in any star near this position.
- Assumed to be Bond 223. On the plates examined the star is always of about the magnitude 13.5. No star near this position has been found to show variation.
- This star is in a strongly nebulous region and the variation is possibly only apparent.
- The star nearest the position is Bond 745, which does not show variation on the plates examined. On each of them it is of about the magnitude 13.5.
- Bond considered this star to be variable. There appears

- to be some fluctuation in light, but on the plates examined, the evidence of variability is not conclusive.
23. Bond 814 is in the position given. On all the plates examined, the light remains at about the magnitude 13.7.
 26. No variation was found in any star near the position given.
 28. A star near this position appeared to be nearly half a magnitude fainter than usual on December 17, 1898. The images of stars in the vicinity are poor, however, and the evidence of variation does not appear to be conclusive. See remark on number 68 in Table I.
 29. The star nearest the position given shows some evidence of variation. On the best plates, the brightness appears to be constant. On January 8, 1894 and January 27, 1895, the star appears nearly half a magnitude fainter than usual, but the images are poor in each case.
 30. Of the two stars near this position, the southern always appears about two tenths of a magnitude the brighter, except on the plates taken November 9, 1896 and December 3, 1901. On these plates the two stars appear equal.
 31. No star near the position given shows variation on the plates examined. See remark on No. 70 in Table I.
 32. The region is covered by only three of the plates examined, and on them the star is too near the edge for accurate observation. The northern of two faint stars near this position was suspected of being half a magnitude brighter on November 10, 1896 than on November 9, 1896. The two stars are doubtless Wolf's 48, 1903 and 54, 1903.
 33. See remark on number 32.
 34. The region is on the edge of the plates examined. No star could be found showing the progressive diminution of light announced by Wolf.
 35. The region is on the extreme edge of the plates examined. No star near the position was found to show variation.

The region covered in this examination was that of Bond's map, which extends between the limits preceding and following θ^1 Orionis by $2^m 42^s$, and from $87'$ north of this star to $91'.5$ south of it. The corresponding limits for 1900 are R.A., $5^h 27^m.7$ to $5^h 33^m.1$, Dec., $-4^\circ 0'$ to $-6^\circ 59'$. The area of this region is 14,458 square minutes of arc, and the number of stars examined about 3,000. A small region near the announced position of each of Wolf's variables, situated beyond the limits of the map, was also examined.

The distribution of the variables contained in Table I emphasizes their close connection with the Nebula. They are found principally in a narrow region on each side of a line extending southward from ϵ Orionis through θ and ι , and beyond. North of declination $-4^\circ 44'$ only one variable was found out of about 900 stars examined. Within the limits of the remainder of Bond's map, out of 550 stars examined, only one variable has been found preceding R.A. $5^h 28^m.4$, and out of 450 stars examined, only one variable has been found following R.A. $5^h 31^m.8$. The areas of these three regions are 3524, 1417, and 2632 square minutes of arc, respectively. In the remaining region, covering 6885 square minutes, out of about 1100 stars examined, 65 have been found to be certainly variable, and 20 more are probably variable. A suspicion is also attached to several other stars not here announced.

It is not improbable that other variables may be discovered when more photographs become available for comparison, as many of those found appear to be of the same class as the variables in globular clusters, which remain at their minimum magnitude during a large part of the time. Those of Wolf's variables which were not confirmed upon the Harvard plates may belong to this class.

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CIRCULAR No. 79.

SEVENTY-SIX NEW VARIABLE STARS.

SINCE the publication of Circular No. 78, in which was given a list of 71 variable stars in the Great Nebula of Orion, a further examination of the region has been made by Miss Leavitt. The plates mentioned in the former circular were superposed successively upon a glass positive made from one of them. In this way, all the variables which show striking changes and are comparatively bright were re-discovered, and eight new ones were found. Six of them are outside of Bond's map, which was the region covered in the previous investigation. Additional plates have been examined for those of Wolf's variables which were not confirmed, with the result that 48,1903 has been found to be certainly variable. On October 26, 1897, its magnitude was 14.8, and on March 3, 1904, it was 13.7. No variation was found in the star north of it, 54,1903. The star 8,1904 does not show variation on the Harvard photographs, being always fainter than the fifteenth magnitude. Marked variation, however, has been found in 11,1904, whose magnitude was 14.9 on January 8, 1894, and 11.4 on January 22, 1897.

An examination has been made of the stars near the Trapezium, which have been suspected of variability by Bond and other observers, especially Nos. 575, 589, 622, 641, 647, 654, 671, and 676 in Bond's Catalogue. On a few plates having short exposures, these stars can be seen, and show apparent fluctuations in brightness. It is probable that photographs taken with a telescope of great focal length, would settle this question.

The positions given by Wolf, of the variables discovered by him, agree very closely with those found from the measures of Bond. In four cases, Nos. 25, 26, 35, and 53, in Table I of Circular No. 78, the positions differ by an appreciable amount. Plates taken on January 25, 1894, and on December 3, 1901, were superposed and examined carefully, but no evidence was found of proper motion during the interval. The right ascension of No. 5, given as $5^h 27^m 54^s.0$ in Table II, should read $5^h 27^m 45^s.0$.

A cursory examination of the vicinity of η Carinae has been made on six plates by the method described above. Ten new variables were found, besides the known

variable, U Carinae. None of these are in the nebula. A similar examination of the Small Magellanic Cloud resulted in the discovery of 57 new variables, including 3 in the cluster 47 Tucanae, which appears on the same plates. These variables may be only a small portion of those actually existing in this region, as nearly all of them were found in a comparison of two plates. The known variable, 005475, in the Provisional Catalogue, Annals, XLVIII, No. 3, and six of the eight known variables in the cluster 47 Tucanae, were also found. A provisional scale of magnitudes has been adopted, as absolute magnitudes of the faint stars have not yet been determined.

A careful examination has been made of the Trifid Nebula. In the region 30' square, whose limits in 1900 extend from right ascension $17^h 55^m.2$ to $17^h 57^m.4$, and from declination $-22^\circ 47'$ to $-23^\circ 17'$, 1167 star images have been examined on two plates and no variable found. A similar examination of N.G.C. 2070, the Looped Nebula in the Large Magellanic Cloud, covered the region whose limits in 1900 extend from right ascension $5^h 37^m.6$ to $5^h 41^m.2$, and from declination $-69^\circ 0'$ to $-69^\circ 20'$. Out of 867 star images examined, two are suspected of slight variability.

TABLE I.
VARIABLE STARS IN ORION AND CARINA.

No.	R. A. 1900.			Dec. 1900.		Br.	Ft.	No.	R. A. 1900.			Dec. 1900.		Br.	Ft.
	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>o</i>	<i>'</i>				<i>h.</i>	<i>m.</i>		<i>o</i>	<i>'</i>		
1	5	24	1	-6	11.3	11.6	<15.4	10	10	16.8	-60	57		10.0	11.5
2	5	25	13	-4	33.9	12.4	13.1	11	10	20.9	-60	24		10.2	12.2
3	5	27	5	-5	0.7	10.0	11.0	12	10	34.6	-58	41		11.4	13.0
4	5	27	8	-2	53.7	9.0	11.4	13	10	34.7	-60	16		13.4	<15.1
5	5	30	25	-5	24.8	11.4	12.5	14	10	36.4	-57	25		11.1	12.8
6	5	30	33	-6	51.7	12.8	13.5	15	10	47.0	-59	49		13.1	<15.1
7	5	32	22	-6	38.6	8.0	10.2	16	10	49.9	-57	59		12.6	14.9
8	5	33	32	-2	48.0	11.6	13.2	17	10	50.2	-57	52		13.7	<15.1
9	5	33	34	-2	47.5	11.4	14.2	18	10	50.4	-58	15		13.4	14.5
								19	10	51.3	-60	24		9.2	10.2

REMARKS.

2. This is the following of two stars which are usually of about the same magnitude.
5. This star is Bond 662.
6. This star is Bond 726.
7. This star is $-7^\circ 1132$, and Bond 1036.
- 8, 9. Apparently these two adjacent stars vary alternately.

On the plates examined, one is always bright when the other is faint.

- 10, 11. These stars are near the edge of the plates examined, and estimates of their brightness were made with difficulty.
19. This star is C.P.D. - $60^\circ 2386$. Variability discovered by Professor E. C. Pickering.

The new variables in Orion and Carina are given in Table I. A number for reference, the right ascension and declination for 1900, and the brightest and faintest magnitudes observed on the plates, are given in the successive columns.

In Table II, the new variables in the Small Magellanic Cloud are given in the same form as Table I.

TABLE II.
VARIABLE STARS IN THE REGION OF THE SMALL MAGELLANIC CLOUD.

No.	R. A. 1900.		Dec. 1900.		Br.	Ft.	No.	R. A. 1900.		Dec. 1900.		Br.	Ft.
	<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>				<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>		
1	0	9.5	-73	11	11.8	13.4	30	0	52.4	-73	44	13.6	14.9
2	0	18.9	-72	40	11.4	13.3	31	0	53.6	-71	48	13.4	14.3
3	0	20.2	-72	27	11.5	12.4	32	0	54.5	-72	57	12.5	13.2
4	0	20.2	-72	38	11.7	12.3	33	0	54.9	-72	19	14.0	14.9
5	0	20.7	-72	36	11.4	12.4	34	0	55.0	-72	58	13.8	15.0
6	0	24.4	-72	44	11.9	12.6	35	0	55.1	-72	59	12.9	14.5
7	0	33.6	-74	31	13.9	14.7	36	0	55.4	-72	27	14.0	14.9
8	0	34.7	-74	30	13.8	14.7	37	0	56.4	-73	25	13.1	14.0
9	0	35.4	-72	34	12.0	13.2	38	0	56.5	-73	59	13.9	14.6
10	0	36.7	-74	14	13.0	14.4	39	0	57.7	-72	44	11.8	13.4
11	0	37.1	-74	16	12.0	13.7	40	0	57.8	-72	42	14.5	15.0
12	0	37.5	-71	10	13.6	14.4	41	0	58.4	-70	34	10.8	<14.5
13	0	38.0	-74	17	10.8	12.1	42	0	59.4	-72	31	13.7	15.2
14	0	38.3	-74	5	13.0	13.8	43	1	0.7	-73	7	13.4	14.9
15	0	40.1	-74	10	12.1	13.3	44	1	2.5	-72	56	13.7	14.5
16	0	43.3	-73	16	11.1	12.0	45	1	2.7	-74	11	13.4	14.2
17	0	44.8	-73	0	12.6	13.7	46	1	3.8	-73	48	11.9	13.2
18	0	45.6	-73	55	13.6	14.3	47	1	4.4	-73	45	12.0	12.9
19	0	45.9	-73	3	12.7	13.9	48	1	4.8	-72	3	12.9	13.7
20	0	46.4	-73	46	13.6	15.0	49	1	5.0	-74	16	12.9	13.5
21	0	46.8	-73	18	11.1	12.1	50	1	5.8	-72	35	13.4	14.7
22	0	47.2	-74	6	14.2	15.0	51	1	7.5	-73	8	13.3	14.3
23	0	47.7	-74	8	14.4	15.0	52	1	7.9	-77	23	11.0	13.4
24	0	47.8	-73	11	12.3	13.6	53	1	10.4	-73	3	13.4	14.3
25	0	49.3	-70	25	9.4	14.3	54	1	10.8	-72	13	12.9	14.7
26	0	50.3	-72	49	11.1	12.0	55	1	26.1	-74	18	11.2	12.0
27	0	50.7	-73	10	13.2	13.9	56	1	32.0	-75	43	11.0	12.5
28	0	52.4	-72	5	12.8	13.7	57	1	38.9	-75	1	11.6	12.5
29	0	52.4	-72	31	11.7	12.8							

Probably, Nos. 11, 13, and 25, are variable stars of long period, while Nos. 9, 10, 18, 20, 28, 31, 33, 34, 36, 44, 46, 48, and 53 have periods that are short.

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variable, U Carinae. None of these are in the nebula. A similar examination of the Small Magellanic Cloud resulted in the discovery of 57 new variables, including 3 in the cluster 47 Tucanae, which appears on the same plates. These variables may be only a small portion of those actually existing in this region, as nearly all of them were found in a comparison of two plates. The known variable, 005475, in the Provisional Catalogue, Annals, XLVIII, No. 3, and six of the eight known variables in the cluster 47 Tucanae, were also found. A provisional scale of magnitudes has been adopted, as absolute magnitudes of the faint stars have not yet been determined.

A careful examination has been made of the Trifid Nebula. In the region 30' square, whose limits in 1900 extend from right ascension $17^h 55^m.2$ to $17^h 57^m.4$, and from declination $-22^\circ 47'$ to $-23^\circ 17'$, 1167 star images have been examined on two plates and no variable found. A similar examination of N.G.C. 2070, the Looped Nebula in the Large Magellanic Cloud, covered the region whose limits in 1900 extend from right ascension $5^h 37^m.6$ to $5^h 41^m.2$, and from declination $-69^\circ 0'$ to $-69^\circ 20'$. Out of 867 star images examined, two are suspected of slight variability.

TABLE I.
VARIABLE STARS IN ORION AND CARINA.

No.	R. A. 1900.			Dec. 1900.		Br.	Ft.	No.	R. A. 1900.			Dec. 1900.		Br.	Ft.
	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>o</i>	<i>'</i>				<i>h.</i>	<i>m.</i>		<i>o</i>	<i>'</i>		
1	5	24	1	-6	11.3	11.6	<15.4	10	10	16.8	-60	57		10.0	11.5
2	5	25	13	-4	33.9	12.4	13.1	11	10	20.9	-60	24		10.2	12.2
3	5	27	5	-5	0.7	10.0	11.0	12	10	34.6	-58	41		11.4	13.0
4	5	27	8	-2	53.7	9.0	11.4	13	10	34.7	-60	16		13.4	<15.1
5	5	30	25	-5	24.8	11.4	12.5	14	10	36.4	-57	25		11.1	12.8
6	5	30	33	-6	51.7	12.8	13.5	15	10	47.0	-59	49		13.1	<15.1
7	5	32	22	-6	38.6	8.0	10.2	16	10	49.9	-57	59		12.6	14.9
8	5	33	32	-2	48.0	11.6	13.2	17	10	50.2	-57	52		13.7	<15.1
9	5	33	34	-2	47.5	11.4	14.2	18	10	50.4	-58	15		13.4	14.5
								19	10	51.3	-60	24		9.2	10.2

REMARKS.

2. This is the following of two stars which are usually of about the same magnitude.
 5. This star is Bond 662.
 6. This star is Bond 726.
 7. This star is $-7^\circ 1132$, and Bond 1036.
 8, 9. Apparently these two adjacent stars vary alternately.

- On the plates examined, one is always bright when the other is faint.
 10, 11. These stars are near the edge of the plates examined, and estimates of their brightness were made with difficulty.
 19. This star is C.P.D. $-60^\circ 2386$. Variability discovered by Professor E. C. Pickering.

The new variables in Orion and Carina are given in Table I. A number for reference, the right ascension and declination for 1900, and the brightest and faintest magnitudes observed on the plates, are given in the successive columns.

In Table II, the new variables in the Small Magellanic Cloud are given in the same form as Table I.

TABLE II.
VARIABLE STARS IN THE REGION OF THE SMALL MAGELLANIC CLOUD.

No.	R. A. 1900.		Dec. 1900.		Br.	Ft.	No.	R. A. 1900.		Dec. 1900.		Br.	Ft.
	<i>h.</i>	<i>m.</i>	<i>o.</i>	<i>'</i>				<i>h.</i>	<i>m.</i>	<i>o.</i>	<i>'</i>		
1	0	9.5	-73	11	11.8	13.4	30	0	52.4	-73	44	13.6	14.9
2	0	18.9	-72	40	11.4	13.3	31	0	53.6	-71	48	13.4	14.3
3	0	20.2	-72	27	11.5	12.4	32	0	54.5	-72	57	12.5	13.2
4	0	20.2	-72	38	11.7	12.3	33	0	54.9	-72	19	14.0	14.9
5	0	20.7	-72	36	11.4	12.4	34	0	55.0	-72	58	13.8	15.0
6	0	24.4	-72	44	11.9	12.6	35	0	55.1	-72	59	12.9	14.5
7	0	33.6	-74	31	13.9	14.7	36	0	55.4	-72	27	14.0	14.9
8	0	34.7	-74	30	13.8	14.7	37	0	56.4	-73	25	13.1	14.0
9	0	35.4	-72	34	12.0	13.2	38	0	56.5	-73	59	13.9	14.6
10	0	36.7	-74	14	13.0	14.4	39	0	57.7	-72	44	11.8	13.4
11	0	37.1	-74	16	12.0	13.7	40	0	57.8	-72	42	14.5	15.0
12	0	37.5	-71	10	13.6	14.4	41	0	58.4	-70	34	10.8	<14.5
13	0	38.0	-74	17	10.8	12.1	42	0	59.4	-72	31	13.7	15.2
14	0	38.3	-74	5	13.0	13.8	43	1	0.7	-73	7	13.4	14.9
15	0	40.1	-74	10	12.1	13.3	44	1	2.5	-72	56	13.7	14.5
16	0	43.3	-73	16	11.1	12.0	45	1	2.7	-74	11	13.4	14.2
17	0	44.8	-73	0	12.6	13.7	46	1	3.8	-73	48	11.9	13.2
18	0	45.6	-73	55	13.6	14.3	47	1	4.4	-73	45	12.0	12.9
19	0	45.9	-73	3	12.7	13.9	48	1	4.8	-72	3	12.9	13.7
20	0	46.4	-73	46	13.6	15.0	49	1	5.0	-74	16	12.9	13.5
21	0	46.8	-73	18	11.1	12.1	50	1	5.8	-72	35	13.4	14.7
22	0	47.2	-74	6	14.2	15.0	51	1	7.5	-73	8	13.3	14.3
23	0	47.7	-74	8	14.4	15.0	52	1	7.9	-77	23	11.0	13.4
24	0	47.8	-73	11	12.3	13.6	53	1	10.4	-73	3	13.4	14.3
25	0	49.3	-70	25	9.4	14.3	54	1	10.8	-72	13	12.9	14.7
26	0	50.3	-72	49	11.1	12.0	55	1	26.1	-74	18	11.2	12.0
27	0	50.7	-73	10	13.2	13.9	56	1	32.0	-75	43	11.0	12.5
28	0	52.4	-72	5	12.8	13.7	57	1	38.9	-75	1	11.6	12.5
29	0	52.4	-72	31	11.7	12.8							

Probably, Nos. 11, 13, and 25, are variable stars of long period, while Nos. 9, 10, 18, 20, 28, 31, 33, 34, 36, 44, 46, 48, and 53 have periods that are short.

EDWARD C. PICKERING.

MAY 26, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 80.

SIX NEW VARIABLE STARS.

An examination of the photographs of the Henry Draper Memorial by Mrs. Fleming has led to the discovery of several variable stars. A list of them is given below, and is followed by a series of notes which give some additional facts. The constellation, approximate right ascension and declination for 1900, and the class of spectrum are given in the successive columns of the table.

Constellation.	R. A. 1900.		Dec. 1900.		Sp.	Constellation.	R. A. 1900.		Dec. 1900.		Sp.
	<i>h.</i>	<i>m.</i>	<i>o</i>	<i>s</i>			<i>h.</i>	<i>m.</i>	<i>o</i>	<i>s</i>	
Auriga	6	4.8	+ 43	11	Md	Ophiuchus	17	29.8	+ 7	19	A
Ursa Major	12	35.8	+ 56	23	Mc5d	Sagittarius	19	13.4	- 31	54	Md
Centaurus	14	43.3	- 42	5	Md	Microscopium	21	17.5	- 41	7	Md

h. m.

6 4.8. An examination of sixteen plates, taken between April 5, 1890, and February 23, 1903, shows a variation of about 2.5 magnitudes in this star.

12 35.8. + 56° 1615, magn. 8.2. An examination of twenty-one plates, taken between April 1, 1890, and December 23, 1902, shows a variation of at least 1.0 magnitude in this star. It was suspected of variability by Mrs. Fleming in the summer of 1890, and was re-discovered independently from its spectrum on May 2, 1904. In 1896, Espin announced in the Monthly Notices, Vol. 56, 238, that observations had been made tending to confirm the variation of this star, and it also appears in the list of suspected variables published with Chandler's Third Catalogue of Variable Stars. Since this star is not contained in any of the Catalogues of known variables, it was thought advisable to include it in the above list.

14 43.3. An examination of eight plates, taken between

h. m.

August 6, 1896, and July 6, 1903, shows a variation of at least 2.5 magnitudes in this star.

17 29.8. + 7° 3404, magn. 9.2. An examination of two hundred and eighty-four plates, taken between August 5, 1890, and May 7, 1904, shows that this is an Algol star, having a variation of about 2.3 magnitudes. It was found in a search for the asteroid (387) Aquitania, by superposition of two plates taken with the Cooke lens in Cambridge on August 8, 1902, and April 12, 1904, respectively.

19 13.4. The following of two close stars in the same declination, one or both of which identifies with C.D.M. - 31° 16579, magn. 9.7. An examination of six plates, taken between November 13, 1894, and July 14, 1902, shows a variation of at least 1.5 magnitudes in this star.

21 17.5. An examination of nine plates, taken between September 8, 1892, and May 14, 1903, shows a variation of at least 3.0 magnitudes in this star.

The plates referred to in the above notes were examined independently by Miss L. D. Wells, who in each case has confirmed the variability of the star.

EDWARD C. PICKERING.

MAY 26, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 51.

NOTES ON VARIABLE STARS OF LONG PERIOD.

THE following notes on Variable Stars of Long Period have been prepared by Miss Annie J. Cannon from her observations with the 6-inch telescope.

The regular working list of the 6-inch telescope of this Observatory consists of the variable stars of long period discussed in Volume XXXVII of these Annals. The variable stars discovered here, and conveniently situated for observation, have been added gradually to the list. Some of the stars discovered several years ago, such as U Persei, R Trianguli, S Ursae Minoris, and RT Cygni, have been observed visually since 1896. These stars have also been observed elsewhere, and their elements and light curves are fairly well known. Therefore, an early publication of the results does not seem to be so important as for other stars for which few or no observations have been published, or for which the published elements do not agree with the observations.

The comparison stars used in observing these variables were those selected for the photographic measurements, and in process of publication in Volume XLVII of these Annals. Photometric observations are in progress to determine the visual magnitudes of these comparison stars, but are as yet incomplete. Preliminary notes are, therefore, given in this paper, and the magnitudes used are on the scale of the Durchmusterung. The photographic measures referred to below were made by Mrs. Fleming and Miss Breslin.

065208. X Monocerotis. Twenty-one observations have been made of this star, but no regular period has been found. On January 30, 1903, when this star was first observed, its magnitude was 7.9. Its light then decreased until, on April 27, 1903, its magnitude was 8.8. A maximum is indicated during January, 1903. Two or more observations were made each month from December, 1903, to May, 1904. The brightest phase occurred during the latter part of January, 1904, after which the variation appeared to be somewhat irregular, between the magnitudes 8 and 9.

083350.—Ursae Majoris. This variable star was announced in 1898. See H. C. O. Circular, No. 36. No letter has yet been assigned to it, and no visual observations have been published. Fourteen observations were made between December 19, 1903, and May 4, 1904. One complete maximum was observed. The variable

rose from invisibility, certainly less than magnitude 12, on December 19, 1903, to approximate equality with $+50^{\circ} 1560$, magnitude 9.4, on March 24, 1904, and had decreased to about magnitude 12, on May 4, 1904. The maximum occurred near the middle of March. This maximum appears to be the first one observed visually, and it accords well with the elements deduced from the photographic observations and published in H. C. O. Circular, No. 77. These elements are J. D. 2412040 + 251 E. According to this formula, the last maximum was on March 18, 1904, and the next will occur on November 24, 1904.

090425. W Cancri. On June 5, 1902, this star was magnitude 8.9. In 1903, the variable was looked for nine times, between February 25 and May 26, but was not certainly seen. In 1904, the variable was invisible on six dates between February 8 and May 6. There is a faint star south of the variable and slightly following, which may be mistaken for the variable when the latter is faint and a low magnifying power is used. The discordance of the observations of 1903 and 1904, when compared with the old elements, led to a new determination of elements using all the available dates of maxima from 1894 to 1901. The elements thus derived are J. D. 2410153 + 384 E. This period is one day longer than that given in Chandler's revised elements in A. J. **24**, 3. Assuming this formula, maxima occurred on June 12, 1902, July 1, 1903, and the next one will occur on July 19, 1904. The long period of invisibility of the star in the 6-inch telescope indicates that the star is very faint at minimum.

140113. Z Bootis. This star was invisible in the 6-inch telescope on May 13 and June 9, 1902, April 21, May 23, May 26, 1903, March 8, March 24, April 4, and April 16, 1904. On May 2, 1904, the variable was first seen as magnitude 12 or fainter. Observations on May 6, 12, 16, and 27, 1904, showed that the light was rapidly increasing. The elements in Circular No. 77, which are J. D. 2414378 + 280 E, give May 17, 1904, as a date of maximum. This date appears to be too early, and the period is probably at least one day longer than that given above. Z Bootis was observed at Bonn as magnitude 9.5 on April 27, 1854, and March 10, 1855, but was missing on April 13, 1853. A period of 281 days satisfies these observations much better than that of 280 days. Assuming the elements, J. D. 2414378 + 281 E, we find that maxima occurred on August 14, 1853, May 22, 1854, and February 27, 1855. The first date accords with the invisibility of the star at Bonn on April 13, 1853. The second and third computed dates of maxima are, respectively, twenty-five days after and eleven days before the dates on which the star was observed at Bonn as magnitude 9.5.

151822. RS Librae. Seven observations have been made of this star, and the following approximate magnitudes have been obtained. In 1903, on May 26, magnitude 9.1, on June 2, 9.3. In 1904, on April 16, invisible in a hazy sky and fainter than magnitude 9.8, on May 3, 9.2, on May 16, 9.0, on May 20, 9.1, and on May 23, 8.9. The elements of the Provisional Catalogue give August 22, 1904, as the date of the next maximum. Since this date appeared to be too late to agree with the observations of the present year, new elements were derived. Eleven maxima deduced from the Harvard photographic observations from 1889 to 1901 were used. The elements thus obtained are J. D. 2410102+219 E. This period is two days shorter than that given in the Catalogue. According to these elements, the next maximum will occur on July 10, 1904.

152714. RU Librae. Six observations have been made. On April 28, 1903, the magnitude of the variable was 9.2. Four later observations showed that the light was decreasing, and on May 25, 1903, the variable was fainter than the magnitude 11. The variable was invisible on April 13 and 21, 1904. These observations do not accord with the elements of the Provisional Catalogue, which gave May 5, 1903, and March 20, 1904, as dates of maxima. A new determination of the elements has therefore been made. For this purpose, nine maxima, deduced from the Harvard photographic observations from 1889 to 1903 and covering sixteen periods, were used. The elements thus derived are J. D. 2410209+314 E. This period is two days longer than that given by Hartwig, in V. J. S. **38**, 248. The elements of the V. J. S. do not agree with the earlier Harvard observations, for they give July 8, 1889, as a date of maximum, whereas the photographs show that RU Librae had passed its maximum, and its light was decreasing in June, 1889.

160210. U Serpentis. No elements and no observed maxima or minima have been published for this variable. Thirteen observations have been made from April 28, 1903, to May 27, 1904. On April 28, 1903, the magnitude of the variable was 9.9, and on June 2, 1903, it was invisible. In September and October, 1903, the variable was increasing, and a maximum is indicated during the latter part of October. Observations from April 13 to May 27, 1904, show that the variable had increased from magnitude 10 to about 8. Measures of the photographic brightness of this star give the dates of ten maxima, covering fifteen periods from 1893 to 1903. The formula J. D. 2410176+240 E has been deduced from these maxima. Assuming this formula, maxima occurred on March 2 and October 28, 1903, and the next date of maximum will be June 24, 1904. The visual observations are in harmony with these dates. U Serpentis was observed at Bonn on July 10, 1852, magnitude 9.0, on

July 12, 1852, magnitude 9.5, but on April 18, 1855, was missing in a clear sky. The elements, J. D. 2410176 + 240 E, give the date of maximum for $E = -52$ as July 26, 1852, sixteen days after the star was first observed at Bonn. It appears, however, from the two Bonn observations of 1852, that the star had already passed its maximum, and was decreasing on July 10, 1852. The date of maximum for $E = -48$ was March 13, 1855, according to these elements, or thirty-six days before the star was invisible at Bonn. An increase of half a day in the period gives the time of maximum as June 30, 1852, for $E = -52$, and February 17, 1855, for $E = -48$. Both of these dates represent the Bonn observations better than those derived from the first formula.

222439. *S Lacertae*. The last published maximum of this star was that of December 19, 1897. Fifteen observations, from September 25, 1903, to January 27, 1904, show that a maximum occurred on October 24, 1903, photometric magnitude 8.2. This is fifty-five days later than the date given by the elements of the Provisional Catalogue, and thirty-six days later than that given by Chandler's revised elements in A. J. **24**, 7. New elements were therefore computed, using seven dates of maxima from 1894 to 1903. The resulting formula is J. D. 2410003 + 237.5 E, which represents the observations of the last ten years, with an average residual of ± 2 days. The next maximum, according to this formula, will occur on June 21, 1904.

EDWARD C. PICKERING.

MAY 30, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 82.

152 NEW VARIABLE STARS IN THE LARGE MAGELLANIC CLOUD.

THE two Magellanic Clouds have long been objects of careful study, on account of the extraordinary physical conditions which prevail in them. They have not, however, heretofore been known as regions in which variable stars are numerous. The discovery of a large number of variable stars in the Small Magellanic Cloud, as announced in Circular No. 79, led to an examination by Miss Leavitt of the Large Cloud, by the same method, although a detailed examination of the region immediately surrounding N. G. C. 2070, the Looped Nebula, had already been made, with negative results. Over one hundred variable stars have thus been found. Twenty-one plates, taken with the Bruce 24-inch Telescope and having exposures of from one to five hours, were used. A series of six of these, taken within ten days of each other, has made it possible to derive some inferences as to the periods.

In Table I, a number for reference, the right ascension and declination for 1900, the brightest and faintest magnitudes observed on the plates, according to a provisional scale, and the range, are given in the successive columns.

The light of nearly all these variables changes rapidly. Among those obviously having short periods are Nos. 20, 23, 53, 59, 60, 62, 65, 66, 68, 69, 72, 78, 80, 81, 89, 102, 103, 107, 113, 126, 131, 132, 134, 135, 142, 152. Their distribution is remarkable, as they are usually found in groups, of which the most definite is in the collection of faint stars and nebulae which begins near N. G. C. 1850 and extends in a southeasterly direction toward a point about a degree south of N. G. C. 2070. These comprise more than half the total number thus far discovered, and appear to be distinguished from the others by their faintness, even at maximum, and their small range of variation. The remaining variables, as a rule, are not found in any of the regions noticeably crowded with stars, though many variables are distributed around the edges of such regions. They show no tendency to be grouped near N. G. C. 2070.

In Circular No. 79, for 662 read 663, in the Remarks on No. 5 of Table I.

TABLE 1.
VARIABLE STARS IN THE LARGE MAGELLANIC CLOUD.

No.	R. A. 1900.	Dec. 1900.	Br.	Ft.	R.	No.	R. A. 1900.	Dec. 1900.	Br.	Ft.	R.
	<i>h. m.</i>	<i>° ' "</i>					<i>h. m.</i>	<i>° ' "</i>			
1	4 55.2	-67 38	13.9	14.8	0.9	42	5 12.5	-69 13	14.1	14.8	0.7
2	4 55.4	-71 4	12.7	14.7	2.0	43	5 13.4	-69 13	14.4	15.0	0.6
3	4 55.8	-70 25	14.3	15.0	0.7	44	5 14.9	-69 19	14.2	14.7	0.5
4	4 57.1	-69 31	13.0	13.7	0.7	45	5 15.0	-67 34	13.5	14.8	1.3
5	4 57.3	-67 31	14.0	14.9	0.9	46	5 15.9	-69 20	14.6	15.0	0.4
6	4 57.5	-68 8	13.8	14.7	0.9	47	5 16.0	-69 11	14.3	15.1	0.8
7	4 58.6	-70 7	12.8	14.5	1.7	48	5 16.1	-70 14	13.9	15.0	1.1
8	4 58.8	-69 36	12.8	14.7	1.9	49	5 16.3	-69 22	14.4	15.0	0.6
9	4 59.2	-67 52	13.9	14.9	1.0	50	5 16.4	-69 10	14.3	14.9	0.6
10	4 59.6	-70 29	13.3	14.8	1.5	51	5 16.6	-69 34	14.2	15.0	0.8
11	5 0.3	-69 36	12.0	14.0	2.0	52	5 17.0	-69 39	14.3	14.9	0.6
12	5 0.5	-68 36	11.7	13.9	2.2	53	5 17.0	-70 42	13.0	14.0	1.0
13	5 1.9	-68 14	11.4	15.5	4.1	54	5 17.2	-69 50	14.7	15.3	0.6
14	5 2.3	-69 3	13.0	14.0	1.0	55	5 17.4	-70 24	14.5	15.1	0.6
15	5 2.9	-66 22	12.8	14.2	1.4	56	5 17.5	-69 26	14.4	15.1	0.7
16	5 2.9	-69 41	13.8	14.9	1.1	57	5 17.9	-70 52	13.6	14.5	0.9
17	5 4.3	-67 24	12.7	14.8	2.1	58	5 18.7	-67 19	12.9	14.0	1.1
18	5 4.3	-69 4	13.1	14.7	1.6	59	5 19.3	-68 20	14.1	14.7	0.6
19	5 4.6	-69 14	14.0	14.6	0.6	60	5 19.4	-70 52	14.4	15.0	0.6
20	5 4.7	-69 10	13.0	15.0	2.0	61	5 19.9	-69 42	13.6	14.6	1.0
21	5 4.8	-68 52	13.8	14.5	0.7	62	5 20.6	-69 16	14.0	14.9	0.9
22	5 6.6	-69 15	13.4	14.9	1.5	63	5 20.6	-68 2	14.2	14.7	0.5
23	5 6.7	-70 42	14.0	15.0	1.0	64	5 20.8	-68 10	14.2	14.6	0.4
24	5 6.8	-68 48	13.7	14.8	1.1	65	5 20.9	-69 42	14.1	14.9	0.8
25	5 7.1	-68 33	14.4	15.0	0.6	66	5 21.3	-70 8	14.3	15.1	0.8
26	5 7.2	-70 56	13.7	15.0	1.3	67	5 21.7	-69 9	12.9	14.0	1.1
27	5 7.3	-68 44	14.3	15.0	0.7	68	5 21.8	-69 54	13.9	15.0	1.1
28	5 7.4	-69 1	13.0	14.7	1.7	69	5 22.8	-69 3	14.2	15.0	0.8
29	5 7.7	-70 10	12.2	13.6	1.4	70	5 22.9	-69 28	14.8	15.1	0.3
30	5 8.4	-69 22	13.9	14.9	1.0	71	5 22.9	-70 15	14.6	15.2	0.6
31	5 8.6	-70 34	13.0	13.8	0.8	72	5 23.0	-69 4	14.4	15.1	0.7
32	5 8.7	-70 47	13.7	14.8	1.1	73	5 23.1	-69 44	14.3	15.0	0.7
33	5 8.8	-68 54	12.2	14.4	2.2	74	5 23.5	-70 1	14.7	15.4	0.7
34	5 9.8	-68 52	13.6	15.0	1.4	75	5 23.6	-69 43	14.2	14.8	0.6
35	5 9.9	-69 2	13.9	15.0	1.1	76	5 24.2	-69 59	13.9	14.8	0.9
36	5 10.4	-67 58	13.8	14.1	0.3	77	5 24.6	-70 5	14.7	15.2	0.5
37	5 10.5	-69 7	14.4	14.9	0.5	78	5 25.1	-68 16	14.9	15.3	0.4
38	5 10.5	-70 34	12.5	13.7	1.2	79	5 25.1	-69 54	14.3	14.9	0.6
39	5 10.6	-68 48	14.3	15.0	0.7	80	5 25.2	-68 17	14.8	15.2	0.4
40	5 11.2	-69 16	13.3	14.6	1.3	81	5 25.4	-69 18	14.1	15.0	0.9
41	5 11.4	-68 14	13.9	14.4	0.5	82	5 25.4	-67 44	11.7	12.8	1.1

No.	R. A. 1900.	Dec. 1900.	Br.	Ft.	R.	No.	R. A. 1900.	Dec. 1900.	Br.	Ft.	R.
	<i>h. m.</i>	<i>° ' "</i>					<i>h. m.</i>	<i>° ' "</i>			
83	5 25.5	-70 1	14.3	15.0	0.7	118	5 31.4	-70 1	14.1	15.2	1.1
84	5 26.0	-67 26	12.8	14.6	1.8	119	5 31.6	-66 34	12.4	14.2	1.8
85	5 26.3	-69 49	14.8	15.1	0.3	120	5 31.6	-70 2	14.5	14.8	0.3
86	5 26.4	-69 10	13.8	14.8	1.0	121	5 31.6	-70 10	14.4	15.1	0.7
87	5 26.8	-69 59	14.3	14.9	0.6	122	5 31.7	-70 0	14.8	15.2	0.4
88	5 26.9	-69 56	14.5	15.1	0.6	123	5 32.2	-70 9	14.7	15.1	0.4
89	5 27.2	-69 41	13.9	15.0	1.1	124	5 32.7	-70 0	14.7	15.2	0.5
90	5 27.2	-69 53	14.8	15.2	0.4	125	5 33.1	-67 59	13.1	14.1	1.0
91	5 27.4	-69 48	14.4	14.9	0.5	126	5 33.4	-68 15	13.6	14.8	1.2
92	5 27.6	-66 58	13.0	14.1	1.1	127	5 34.3	-67 41	13.7	14.7	1.0
93	5 27.7	-67 21	13.8	15.5	1.7	128	5 34.6	-67 53	13.6	14.4	0.8
94	5 28.0	-69 55	14.3	14.8	0.5	129	5 34.6	-68 3	14.0	14.8	0.8
95	5 28.0	-71 16	13.8	15.2	1.4	130	5 35.5	-67 48	13.6	14.2	0.6
96	5 28.1	-70 24	14.9	15.3	0.4	131	5 35.9	-66 46	12.2	13.8	1.6
97	5 28.1	-69 55	14.3	14.8	0.5	132	5 36.1	-68 36	12.3	13.4	1.1
98	5 28.1	-68 28	13.8	14.4	0.6	133	5 36.2	-67 0	13.8	14.8	1.0
99	5 28.3	-69 48	14.7	15.1	0.4	134	5 36.8	-68 53	13.0	14.6	1.6
100	5 28.4	-67 8	13.9	14.7	0.8	135	5 38.1	-69 32	13.4	14.8	1.4
101	5 28.4	-69 55	14.2	14.7	0.5	136	5 38.6	-68 8	13.9	14.9	1.0
102	5 28.8	-70 5	13.2	14.8	1.6	137	5 38.6	-70 19	14.5	15.0	0.5
103	5 29.0	-69 53	14.1	15.0	0.9	138	5 38.7	-70 18	14.9	15.2	0.3
104	5 29.5	-69 45	14.4	15.5	1.1	139	5 39.0	-70 5	14.4	15.1	0.7
105	5 29.5	-69 45	14.8	15.2	0.4	140	5 40.0	-70 22	14.2	15.1	0.9
106	5 29.5	-69 45	14.8	15.5	0.7	141	5 40.0	-70 42	14.4	15.2	0.8
107	5 29.6	-70 2	13.8	15.0	1.2	142	5 40.3	-67 53	13.2	14.2	1.0
108	5 29.8	-69 55	14.1	15.1	1.0	143	5 40.4	-70 23	14.5	15.0	0.5
109	5 30.2	-67 37	14.4	15.0	0.6	144	5 40.5	-69 6	14.0	14.5	0.5
110	5 30.2	-69 50	14.1	14.9	0.8	145	5 40.7	-70 24	14.6	15.1	0.5
111	5 30.5	-69 13	13.8	14.1	0.3	146	5 41.7	-69 21	14.4	14.9	0.5
112	5 30.6	-70 18	14.7	15.2	0.5	147	5 43.7	-66 52	14.5	15.0	0.5
113	5 31.0	-69 31	13.3	14.2	0.9	148	5 44.0	-70 10	13.9	14.7	0.8
114	5 31.0	-69 57	14.0	15.0	1.0	149	5 44.3	-68 43	14.2	14.7	0.5
115	5 31.2	-67 30	13.1	14.3	1.2	150	5 45.3	-69 34	14.6	15.1	0.5
116	5 31.3	-70 9	14.6	15.2	0.6	151	5 46.3	-69 16	14.4	14.9	0.5
117	5 31.3	-70 42	14.4	15.1	0.7	152	5 47.2	-68 12	13.2	14.4	1.2

REMARKS.

13. This star has the largest range of any of the variables in Table I. The period is probably long.

15. The preceding star of a pair.

23. The central star of a close cluster of five.

25. A faint star north of and closely following the variable makes it appear nebulous, except on plates in which the definition is good.

30. The preceding star of a close pair.

36. The variation of this star seems to be real, although the observed range is small.

46. Variation well shown, though small.

53. Period apparently extremely short.

61. The northern star of a close pair.

64. Variation well shown, though small.

70. The variation of this star seems to be real, although the observed range is small.

- 78, 80. These adjacent stars apparently vary alternately. On the plates examined, one is always bright when the other is faint. Period apparently short.
85. The variation of this star, although small, seems to be real, as there are good comparison stars near it.
90. The variation is well shown.
96. The variation is well shown.
- 104, 105, 106. These three stars are very near together. The periods of all are evidently short. Nos. 105 and 106 were discovered by Mrs. Fleming while confirming adjacent variables.
110. This star may be of the Algol type. It is of uniform brightness on nearly all of the plates examined, but is faint on two plates.
111. The variation of this star seems to be certain, although the observed range is small.
119. This star is faint on only three plates.
120. This star is certainly variable, although the observed range is small.
122. Variation well shown.
123. Variation well shown.
138. The variation of this star is certainly real, although the observed range is small.
144. This star was observed as slightly variable in the previous examination of the region near N. G. C. 2070. Additional plates have confirmed the variability with a larger range than was observed at that time.

The variability of all of these stars, and of those announced as variable in Circulars Nos. 78 and 79, have been confirmed either by Mrs. Fleming or by Miss Leland. It is probable that the range will be increased when a photometric scale is substituted for that here used. Many of the faint stars in the Large Magellanic Cloud show slight fluctuations in brightness. This renders it probable that many more variables may be discovered from an examination of later plates.

Preparations are being made for determining the precise positions, periods, and light curves of all of these variables. The treatment should be like that of the 128 variables in ω Centauri, discussed in Volume XXXVIII. This will be a large piece of work, and progress will necessarily be slow. Two or three assistants should be started on the work at once.

The total number of new variables found in nebulous regions by Miss Leavitt, and announced in Circulars Nos. 78, 79, and 82, is at least 277. It is a remarkable illustration of the results to be expected from a systematic study of the Harvard Library of Astronomical Photographs. During 1903, a grant from the Carnegie Institution permitted a corps of eight or more observers to carry on such investigations. Since then this corps has been disbanded, and the means of the Observatory have permitted but one observer to be employed on similar work, with the results here shown.

EDWARD C. PICKERING.

JUNE 21, 1904.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 83.

COMMON'S 60-INCH TELESCOPE.

AN important part of the work of the Harvard College Observatory for the last quarter of a century, and of the writer personally, has been the determination of the light of the stars. About one hundred thousand measures of four thousand stars, including all those visible to the naked eye in Cambridge, and all those of the sixth magnitude and brighter, north of declination -30° , were made in 1879 to 1881. The telescope used in this work had an aperture of only two inches. A similar instrument, with an aperture of four inches, has been in use here and in Arequipa, since 1882. More than a million settings, on nearly sixty thousand stars, in all parts of the sky from the North to the South Pole, have been made with it. Numerous standards of the tenth magnitude and brighter are thus provided. In 1899, a telescope of twelve inches aperture was mounted horizontally, and used in a similar manner. Since then, four hundred thousand measures of about eleven thousand stars have been made, thus furnishing standards of the twelfth magnitude and brighter.

As this Observatory has not heretofore owned a very large telescope, we have had to rely on the courtesy of our friends for measures of the fainter stars. By means of an appropriation from the Rumford Committee, and with the coöperation of the Directors of the Yerkes, Lick, McCormick, and Halsted Observatories, several of the largest telescopes in the world have taken part in a determination of standard magnitudes of very faint stars. A request for a telescope of the largest size, to be mounted at Harvard, has not hitherto been made, since the atmospheric conditions in the eastern part of the United States and in Europe are not so favorable to the best work as in certain selected stations in the tropics. By a modification of the twelve-inch telescope described above, good measures can be made of the stars, even if their images are bad. By reducing the image of the real star, instead of that of the artificial star, more accurate measures may be made, certain sources of constant error eliminated, and since both images are faint when compared, defects in them are rendered imperceptible. In this way, even so large an object as the planet Mars has been satisfactorily compared with an artificial star.

A reflecting telescope of sixty inches aperture was constructed by the late A. A. Common, and for several years has been idle. From its great aperture it should show extremely faint stars, and would be especially adapted to measuring their light. Some years ago, an attempt was made to purchase this telescope, but the means of the Observatory would not then permit. In 1902, the anonymous gift of \$20,000 was received, and it has supplied several urgent needs of the Observatory. Representing these facts to Professor Turner of Oxford, during his recent visit to Harvard, he recognized the importance of utilizing so valuable an instrument, and that the nature of the observations and other conditions were favorable to securing valuable results. He therefore wrote to Mr. T. A. Common, with the result that this Observatory has purchased the telescope on such liberal terms that Mr. Common may fairly be regarded as having contributed a large portion of the cost.

Steps are being taken for packing and transferring the instrument at once to Cambridge. It is hoped that in a few weeks the telescope may be received and mounted, and that observations to supply one of the great wants of Astronomy, a measure of the light of the very faint stars, can then begin. The work of many years has supplied this want for the brighter stars, and may now be extended to the faintest objects within the reach of human knowledge.

We have here another illustration of the valuable results which may be obtained in Astronomy, from a combination of favorable circumstances. It is still another result of the utmost importance derived from a gift made without restrictions. It affords an opportunity to make useful the greatest work of one of the most successful of the makers of large telescopes. It secures the liberal aid of his family through the friendly assistance of a brother astronomer. All have been brought together through a form of investigation which appears especially suited to these particular conditions.

EDWARD C. PICKERING.

AUGUST 18, 1904.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 84.

CARNEGIE GRANT OF 1903.

THE Harvard Circulars have hitherto been used mainly for the announcement of discoveries and similar facts of scientific interest. It is believed that they will also be found a convenient means of notifying astronomers of financial and other matters relating to Astronomy.

The Harvard collection of photographs, or photographic library, now contains more than one hundred and fifty thousand glass negatives. On the average, photographs are included of every portion of the sky, taken on about two hundred nights, from 1889 to the present time, and showing stars as faint as the eleventh magnitude. Bright stars are photographed on a much larger number of nights, especially in recent years. A nearly continuous history of the sky, such as does not exist elsewhere, is thus furnished, from which a detailed study of almost any celestial object may be made. Representing these facts to the Trustees of the Carnegie Institution, they courteously made me a grant of \$2500 for the year 1903, for the study of these photographs. This aid has permitted a large amount of material to be collected, and is gratefully acknowledged. A description of the work accomplished is given in my report to the Trustees, dated October 3, 1903. As only an abridged notice of this report has been published (Carnegie Year Book, No. 2, 1903, page xxi), permission has been granted me to make a fuller statement. My objects in doing this are, first, because I believe that the results will be of interest to astronomers, and there seems to be no immediate prospect that the detailed publication, which was expected, can be made except very slowly. Secondly, it is hoped that if it becomes known that so large an amount of valuable material has been secured in proportion to the expenditure, steps may be taken to insure its publication and the continuation of the work.

On December 6, 1902, notification was received that the appropriation had been made, and that it would be available only during the year 1903. Early in January, 1903, eight or ten assistants were at work on some of the researches described below, and this number was maintained during the year. No money was used for executive expenses, and nearly the entire grant was expended on routine observing,

computing, and copying, at the rate of twenty-five or thirty cents an hour. Excellent assistants, both men and women, can be obtained here at these rates. On December 19, 1903, notification was received that the grant would not be continued for 1904, and the work was accordingly stopped on December 31, 1903. The shortness of the notice must be my excuse for not completing and publishing a portion of the work.

The collection of photographs may be regarded as a unique library for which there are few readers or students. A corps of experts should be employed, whose duties would be to conduct researches like those described below, and especially to prepare for publication the past history of newly discovered objects. It is believed that \$5,000 annually could be wisely expended in this work. Of this, \$3,000 should be spent for routine work, \$1,000 for supervision and preparation for publication by advanced assistants, and \$1,000 for printing. It is hoped that each year the results would fill a quarto volume of two or three hundred pages.

It is difficult to realize the immense amount of material here at command. To an astronomer elsewhere half of the stars are always below the horizon, and a part of them are never visible to him unless he crosses the Equator. More than half of the time the Sun is above the horizon, or so near it that the twilight renders observation impossible. Clouds prevent observation for at least half of the time. Even the intervals remaining for work are diminished, since a star cannot be observed when near the horizon. At Cambridge, we have photographs of the entire sky, on two hundred or more nights, and can thus at any time study the history of any object during the last fifteen years. By comparing different photographs, observations can be repeated again and again, and observed changes can thus be verified.

From the variety of important investigations which presented themselves, it was difficult to decide which should be selected. It seemed best to undertake a number, as examples. Many of them, like Nos. 3, 4, 5, 6, 10, and 11, described below, could be extended almost indefinitely. The breadth of the field and its possibilities were thus better shown than if a single research had been undertaken. An early publication of some of the results was made in H. C. O. Circulars, Nos. 69 and 70.

While the results given below illustrate what may be expected if the work is continued, it is probable that still greater economy would ensue from making the work continuous, from removing the limiting dates of expenditure of the appropriations, and from avoiding the loss due to forming and disbanding a corps which should consist of experienced workers. Each year the value of the results should

increase, and it is hoped that a donor may be found who will consider such results an adequate return for the expenditure.

The researches carried on in 1903 are as follows:—

1. *Eclipses of Jupiter's Satellites*.—Photographs of Jupiter's Satellites while undergoing eclipse have been taken on 122 nights, since July 24, 1888. Generally, the plate was moved automatically every 10 seconds, thus forming a series of images showing the gradual change in brightness. About eleven thousand measures have been made of these plates, and it is expected that they will serve to determine the time of eclipse with great accuracy. They will thus supplement the series of visual observations made here during the last twenty-five years.

2. *Light curves of Algol Variables*.—674 photographs of eight variable stars of the Algol type have been taken near the time of minimum, since September 8, 1891. The plates were moved automatically, at intervals of exactly one or more minutes. It is expected that the measures of the resulting images will give good determinations of the times of minima, and of the form of the light curves. About nine thousand measures have been made of 364 plates, of W Delphini, S Cancri, SW Cygni, and UW Cygni.

3. *Positions and brightness of stars in clusters*.—Photographs have been taken of several coarse clusters and have been measured in a way that combines accuracy and economy. As an example, about 1500 stars have been measured in the Cluster in the Sword Handle of Persens. All stars in a region having an area of six tenths of a square degree, and brighter than the fifteenth magnitude, are included. From one to four measures were made of each star by each of two observers. The accidental errors of measurement are about a second of arc and a tenth of a magnitude. The cost of measuring a star by this method is about half a cent. 265 stars near the new star in Gemini have also been measured in this way. It is believed that this will prove a convenient method of forming useful catalogues of the stars in such regions.

4. *Variable Stars of long period*.—Observations have been made of the changes in light of nine recently discovered variable stars of long period, during several years before they were known to be variable. An example of one of these is given in Circular No. 69.

5. *Early observations of stars of the Algol type and other variables of short period*.—These observations have special value since they serve to determine the periods of these stars with great accuracy. An example of this kind is given in Circular No. 69.

6. *Transit photometer*.—For many years the sky has been patrolled every clear night at Arequipa and Cambridge by two similar transit photometers. All stars brighter than the sixth magnitude, and which cross the meridian after dark, are photographed. Much time has been spent in studying these photographs, identifying the stars, etc. The variations in light of α Orionis seem clearly proved from these plates. Owing to the distance of the comparison stars, ordinary photographs cannot be used. On account of its color and brightness, visual observations of its variations are very uncertain.

7. *Nova Geminorum*.—Our knowledge of the early variations in light of this star depends almost entirely upon the measurements made here, and described in Circular No. 70.

8. *Variations in brightness of Eros*.—The curious change in light of this planet was discovered in February, 1901. 1755 measurements have been made of the variations before then, and these are expected to add greatly to our knowledge of this remarkable phenomenon.

9. *Proper motions of stars*.—The absence of proper motion of $-1^{\circ}3359$ is shown in Circular No. 69.

10. *Missing asteroids*.—Much useful work could be done in finding asteroids which are lost, not having been seen for several years. Two examples are given in Circular No. 69.

11. *Miscellaneous objects*.—Many images of interesting objects, like new stars, variables, and asteroids, doubtless appear on the photographs. An examination has accordingly been made of several of the plates to determine whether it would be advisable to examine a large number of them systematically for the discovery of such objects.

Investigations Nos. 1, 2, and a part of 3, have been carried on under the direction of Mr. Edward S. King, with the assistance of Messrs. Braseh, Colson, Ellenbogen, Lynn, Morgan, Sanderson, and Thibault. The remainder of No. 3, and Nos. 4 to 11 have been carried on under the direction of Mrs. Fleming, with the assistance of Misses Breslin, Cushman, Gill, Harriman, Leavitt, Lekund, Landin, McCoy, McKay, H. I. Stevens, I. M. Stevens, and Wells.

After the corps was disbanded, one observer, Miss Leavitt, was retained at the expense of the Observatory, to continue similar work. In the course of the following few weeks she discovered 277 new variable stars, all in large nebulous regions, as described in Circulars Nos. 78, 79, and 82.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 85.

THE ANONYMOUS GIFT OF 1902.

IN 1902, a gift of twenty thousand dollars was made to the Observatory, with the sole condition that the name of the donor should not be divulged. This gift was particularly acceptable from the way in which it was presented. It was unsolicited, and it was received from one on whom the Observatory had no claim. It is believed that the results obtained through this gift are so valuable that a statement of them will be of interest to astronomers, and that it will show the friends of the Observatory that any sums of money, either large or small, can be expended in a way that will lead to relatively great scientific results.

Circular No. 84 showed the results obtained in one year from an increase of \$2,500 in the income of the Observatory, by a grant from the Carnegie Institution, for the study of the Harvard collection of astronomical photographs. The results obtained from the expenditure of the Anonymous Gift of 1902, equivalent to the addition of \$20,000 to the capital of the Observatory, but available for immediate needs, is given below:—

1. In 1892, the friends of the Observatory presented it with a Photographic Library, consisting of a plain, three story, brick building for holding and studying its collection of astronomical photographs, then containing about thirty thousand glass plates. In 1902, this collection had increased to about one hundred and thirty thousand plates, and more room for storing them was urgently needed. A wing which will accommodate two hundred thousand more plates was accordingly added to the Photographic Library. It is of brick, fire proof, and three stories high. Each floor is about thirty feet square, of extended metal construction, and calculated to carry a weight of five hundred pounds to the square foot. As the growth of the collection is about ten thousand negatives a year, provision has thus been made which will supply for many years an urgent need of the Observatory. The building was erected under the supervision of Professor Burke, Inspector of College Buildings, thus insuring the best construction and a great saving in cost.

2. Experiments at the Yerkes and Lick Observatories have shown that faint stars and nebulae can be photographed with large reflectors, although quite beyond

the reach of other telescopes. Accordingly, in 1902, when the very interesting nebula surrounding the New Star in Perseus, No. 2, was found to be in rapid motion, the Harvard Observatory could not take part in its study. Moreover, no large reflector is permanently mounted in the southern hemisphere, which is available for a general study of the stars not visible in the United States and Europe. The Harvard Observatory has a station in Arequipa, Peru, where the atmospheric conditions, as well as the latitude, are especially suited to such work. Accordingly, a silver on glass mirror, having a diameter of twenty-four inches, has been made by the firm of Alvan Clark & Sons. A mounting has been constructed here, under the direction of Mr. Gerrish, an officer of the Observatory, with a great saving of expense. In fact, the total cost has been so small that a second mirror has been made, with the expectation of maintaining one in Cambridge and the other in Arequipa.

3. A statement has been made in Circular No. 83, of the exceptional conditions under which we have acquired the 60-inch telescope of the late A. A. Common. The Observatory is thus in possession of a telescope larger than any now in use, and expects to employ it in a way that will secure important results, without the favorable atmospheric conditions found in certain tropical countries.

4. This gift has also provided for numerous smaller, but urgent, needs of the Observatory. The capital of our other funds could not be used for them, and the entire income was required for other expenses. A 6-inch hydrant has been erected on the grounds, and frequent fire drills render it probable that effective streams of water would be turned upon a fire several minutes before the city engines could reach here. The executive work of the Observatory has been greatly expedited by the construction of a revolving table, which places the equivalent of a table twenty feet long, with six bookcases and twelve drawers, within the immediate reach of the person using it.

Through this gift, the permanent plant of the Observatory has been improved by an amount which, except for these favorable conditions, would have required a much larger expenditure.

EDWARD C. PICKERING.

AUGUST 27, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 86.

THE NEBULA OF ORION.

THE late Isaac Roberts, only a few days before his death, wrote me a courteous note in which he called my attention to the fact that several of the variables in the Nebula of Orion had already been announced by him in the Monthly Notices of the Royal Astronomical Society, L, 316. I am also indebted to him for four excellent photographic prints of this nebula, taken on February 4, 1889, January 15, 1896, February 14, 1898, and January 3, 1903, with exposures of 205, 90, 40, and 90 minutes, respectively. An examination of these photographs by Miss Leavitt has led to the results enumerated below. Dr. Roberts' variables are enumerated in Table I, and the numbers assigned to them by him, by Professor Wolf, by Miss Leavitt, and by Bond, are given in the first four columns.

TABLE I.

Roberts No.	Wolf No.	Harvard No.	Bond No.	R. A. 1900.		Dec. 1900.		Roberts No.	Wolf No.	Harvard No.	Bond No.	R. A. 1900.		Dec. 1900.	
				<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>					<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>
1	..	19	417	5	29	42.5	-6 9.6	6	..	..	..	5	32	39.	-5 16.3
2	40,1903	26	509	5	30	1.6	-5 50.6	7	..	..	492	5	29	57.5	-5 7.5
3	41,1903	34	582	5	30	16.3	-5 50.5	8	..	..	..	5	30	43.	-5 10.1
4	..	52	817	5	30	54.0	-5 53.5	9	42,1903	35	596	5	30	19.4	-4 49.7
5	..	..	999	5	32	4.8	-5 27.8	10	..	32	561	5	30	13.6	-4 31.7

REMARKS.

- This star is conspicuously bright on the photograph taken by Dr. Roberts on January 3, 1903, but is not seen on his other three photographs. It has not been certainly identified on any of the Harvard photographs mentioned in Circular No. 78, although four of them show star images fainter than any seen on Dr. Roberts' photographs. As the star is on Bond's chart, there appears to be no doubt as to its existence.
- The variation in this star, as seen on the four photographs taken by Dr. Roberts, is slight. A variation of two or three tenths of a magnitude is also seen on

the Harvard photographs. It is never brighter than Bond 1061, but is sometimes brighter and sometimes fainter than Bond 987. It is always brighter than a star of magnitude 14.5, having coordinates $+2^{\text{h}} 21^{\text{m}}$ in right ascension, and $+15^{\circ} 2'$ in declination, which is not on Bond's map.

- This star is No. 10 in Table II of Circular No. 78. The variation is conspicuous on the photographs taken by Dr. Roberts, which show it to have been more than a magnitude brighter on January 3, 1903, than on the other photographs.

8. No star can be found in this position either on the four photographs taken by Dr. Roberts, on the photograph taken with the Yerkes 24-inch Reflector on October 19, 1901, (see The Decennial Publications of the University of Chicago, Volume VIII, Plate XXIII), or on any of

the Harvard photographs mentioned in Circular No. 78. Unless there is a mistake in the position as announced, this star probably resembles No. 5 in its manner of variation.

It will be noticed that the right ascensions of several stars in the above table differ slightly from those given in Circular No. 78. This is due to a correction for difference in precession, at different declinations, omitted in the earlier table.

The stars in Table II of Circular No. 78, and also several others which have been suspected of variability here, were looked for on the photographs taken by Dr. Roberts. Thirteen stars, found to be certainly variable, have been confirmed by Mrs. Fleming, and are given in Table II, in which Nos. 76, 78, 80, 88, and 90 correspond to Nos. 6, 8, 9, 24, and 25, in Table II of Circular No. 78. In order that the enumeration of variables in this region may be continuous, Nos. 1 to 9 in Table I of Circular No. 79 have been inserted in Table II, and the numbers 72, 73, 74, 75, 85, 87, 91, 93, and 94 have been assigned to them. Wolf's variables, 48, 1903 and 11, 1904, which have been confirmed here, are also included as Nos. 95 and 92. In Table II, the successive columns give a number for reference, the Bond number, the corrected right ascension and declination for 1900, the brightest and faintest magnitudes on the Harvard plates, and the brightest and faintest magnitudes on the photographs taken by Dr. Roberts, after reducing them to the same scale. Nos. 72, 73, 74, 75, 87, 89, 91, 92, 93, 94, and 95 are outside the region covered by Dr. Roberts' photographs.

TABLE II.

No.	Bond.	R. A. 1900.			Dec. 1900.		Harvard.		Roberts.		No.	Bond.	R. A. 1900.			Dec. 1900.		Harvard.		Roberts.	
		h.	m.	s.	°	'	Br.	Ft.	Br.	Ft.			h.	m.	s.	°	'	Br.	Ft.	Br.	Ft.
72	..	5	24	1.	-6	11.3	11.6	<15.4	..	..	84	..	5	29	55.	-5	46.4	14.3	14.6	13.2	14.0
73	..	25	13.		-4	33.9	12.4	13.1	..	..	85	663	30	25.4		-5	24.8	11.4	12.5	..	..
74	..	27	5.		-5	0.7	10.0	11.0	..	..	86	..	30	33.		-6	5.4	14.9	<15.4	14.1	<14.5
75	..	27	8.		-2	53.7	9.0	11.4	..	..	87	726	30	32.8		-6	51.7	12.8	13.5	..	..
76	216	28	50.7		-5	35.3	13.0	14.0	13.1	14.1	88	..	31	6.		-6	1.3	14.1	14.5	13.0	<14.0
77	270	29	7.4		-5	40.7	14.2	14.5	14.0	14.3	89	866	31	6.2		-6	40.7	14.2	15.0	..	..
78	..	29	22.		-5	36.5	14.6	15.0	13.1	14.2	90	..	31	38.		-5	20.8	14.6	<15.0	14.0	<14.3
79	..	29	20.		-5	38.0	14.1	14.7	13.2	14.1	91	1036	32	21.6		-6	38.6	8.0	10.2	..	..
80	361	29	30.0		-5	1.1	14.2	<15.0	13.6	14.3	92	..	32	35.6		-1	49.9	11.4	14.9	..	..
81	..	29	30.		-5	1.4	13.6	14.1	13.7	14.2	93	..	33	32.		-2	48.0	11.6	13.2	..	..
82	..	29	31.		-5	1.4	14.8	15.3	13.9	14.5	94	..	33	34.		-2	47.5	11.4	14.2	..	..
83	478	29	54.6		-5	46.1	12.9	13.3	12.4	12.9	95	..	35	57.8		-8	8.5	13.7	14.8	..	..

REMARKS.

35-9

- | | |
|--|--|
| 80, 81, 82. There is not sufficient material available at present, to determine whether these three adjacent variables change relatively to one another. | 86. A star of the magnitude 14.5 precedes this variable 0 ^m .9 and is 0.4' north of it.
91. This star is -6° 1259. Observations made on 114 plates indicate that the variations are irregular. |
|--|--|

Many of the above variables appear brighter, even at minimum, on the photographs taken by Dr. Roberts than on the Harvard plates. This difference may be due to color, the selective absorption of a reflector differing greatly from that of a refractor.

Attention has more than once been called to the fact that on different plates the images of extremely faint stars often show apparent changes which do not indicate real variability. This has long been observed here, and constantly guarded against, especially in the present study of variables in nebulous regions. Usually there is no doubt in the mind of the observer as to whether apparent variation is real or only photographic. All cases admitting of the slightest doubt have from the first been excluded. A test of the reality of the changes in the variables announced, is found in the fact that some regions, notably that surrounding η Carinae, have been examined on plates of similar quality to those used for the regions of Orion and the Magellanic Clouds, and no evidence found of any general tendency to variability.

EDWARD C. PICKERING.

SEPTEMBER 5, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 87.

THE NINTH SATELLITE OF SATURN.

It is probable that, in the future, there will be no difficulty in securing a sufficient number of observations of Phoebe, the Ninth Satellite of Saturn, not only to correct the present elements, but to study the large and interesting perturbations to which it is subject. It can be observed visually with the largest refractors, and can doubtless be photographed with large reflectors, as well as with the Bruce Telescope, by the aid of which Professor William H. Pickering discovered it. Since the observations enumerated by him in the Harvard Annals, LIII. 55, 60, Phoebe has been closely followed by Professor Bailey. The approximate positions obtained by him, with the Bruce Telescope, are given in Table I, and the positions found by Professor Barnard visually on August 8 and September 12, 1904, with the 40-inch Yerkes Telescope, and announced in the Harvard Bulletins, Nos. 157 and 159, are added, to bring together all the material so far collected. The designation of the plate, the date, Greenwich Mean Time, exposure, and rectangular coördinates referred to Saturn as an origin, are given in the successive columns.

TABLE I.

POSITIONS OF PHOEBE.

Desig.	Date.	G. M. T.	Ex.	<i>z</i>	<i>y</i>	Desig.	Date.	G. M. T.	Ex.	<i>z</i>	<i>y</i>
	1904.	<i>h. m.</i>	<i>m.</i>	<i>′</i>	<i>′</i>		1904.	<i>h. m.</i>	<i>m.</i>	<i>′</i>	<i>′</i>
A 6771	June 18	18 20	120	+24.20	+6.65	A 6844	August 4	14 44	..	+10.86	+1.61
A 6773	" 20	18 30	120	+23.84	+6.65	A 6846	" 5	14 32	..	+10.60	+1.37
A 6801	July 6	16 15	120	..	..	...	" 8	18 0	..	+ 9.70	+0.98
A 6804	" 7	16 14	120	..	..	A 6854	" 15	19 15	..	+ 6.83	+0.15
A 6807	" 11	16 58	180	..	..	A 6856	" 16	18 51	..	+ 6.49	0.00
A 6841	August 2	14 47	..	+11.56	+1.85	...	Sept. 12	12 36	..	+ 5.93	-4.28

For some unexplained reason, Phoebe has not been found on the plates taken in July. The record for the plates taken in August, has not yet been received from Arequipa.

A NEW VARIABLE IN HERCULES.

365

The meridian photometer, like other meridian instruments, is not adapted to the discovery of variable stars. It may therefore be of interest to note the discovery of such an object by the writer, with the 12-inch Meridian Photometer. On August 23, 1904, while measuring the star $+24^{\circ} 34' 19''$, magn. 9.4, it was noticed that a brighter star, having the photometric magnitude 9.5, and not in the Bonn Durchmusterung, preceded it. An examination, the next day, of the photographs of this region, at once showed that the star was a variable of long period having a range extending at least from the magnitude 9.5 to <13 . The approximate position for 1855, is R.A. $18^h 20^m 26^s.0$ Dec. $+24^{\circ} 56'.4$.

EDWARD C. PICKERING.

SEPTEMBER 12, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 88

5150

A NEW ALGOL VARIABLE. — 15° 4905.

IN the course of an examination of plates in the region of Sagittarius, a star which usually appeared to be constant in brightness was noticed by Miss Leavitt to be half a magnitude fainter than usual on one of the plates. Additional plates were examined, and the star was found to be a variable of the Algol type. Over three hundred plates were available for the study of the new object, on twenty-eight of which it is fainter than the normal brightness, magnitude 9.55. In three cases, it appears faint on two plates taken during the same night, so that twenty-five different minima have been observed. The observations indicate that the times of minimum may be represented by the formula J. D. 2,410,002.677 + 3.45348 E. An interesting feature in the variation is found in the fact that a secondary minimum occurs midway between the primary minima represented by the formula.

The observations when the variable was faint are given in Table I, in which seven plates, taken during the secondary minimum which occurred on the night of September 28, are included. The first three columns give the year, month, and day on which the plate was taken, the Greenwich Mean Time of the centre of the exposure, and the Julian Day and fraction, following Greenwich Mean Noon. The fourth column contains the observed magnitude, and the fifth the number of the epoch. The sixth column gives the residual found by subtracting the computed time of minimum from the observed time, secondary minima being enclosed in parentheses. The last column gives the residual expressed in magnitudes from the assumed light curve.

The majority of the observations satisfy the adopted formula very well, especially when it is considered that on a large proportion of the plates the variable is near the edge, so that the observations are somewhat uncertain. On J. D. 5224.578, corresponding to the phase + 0.240, the observed magnitude was 9.85. Although the variable is near the edge of the plate, the image is good,

and appears to be actually faint. This observation, if correct, suggests a longer duration of the eclipse than is indicated by the other observations. The image on the plate taken on J. D. 5890.823 appears to be defective, but the variable is certainly faint.

TABLE I.
OBSERVATIONS NEAR MINIMUM.

Date.			G. M. T.		J. D.	Magn.	Epoch.	Phase.	Resid.
<i>y.</i>	<i>m.</i>	<i>d.</i>	<i>h.</i>	<i>m.</i>					
1889	7	6	15	26	1190.643	10.37	344	-0.031	-0.08
1890	8	2	14	13	1582.592	9.85	457	(-0.052)	+0.02
1893	5	1	20	54	2585.871	10.31	748	-0.009	-0.20
"	"	"	21	8	2585.881	10.51	748	+0.001	-0.04
1895	5	29	19	50	3343.826	9.97	967	(-0.092)	+0.17
1896	7	1	16	19	3742.680	10.11	1083	-0.116	+0.10
"	10	13	12	21	3846.515	9.81	1113	+0.115	-0.18
1897	6	1	19	43	4077.822	10.58	1180	+0.039	+0.03
"	8	30	12	38	4167.526	<10.2	1206	-0.048	..
1898	10	8	12	35	4571.524	9.99	1323	-0.107	-0.07
1899	6	10	18	43	4816.780	10.45	1394	-0.048	+0.07
"	7	25	15	10	4861.632	10.26	1407	-0.091	+0.08
"	9	27	12	31	4925.522	9.79	1425	(-0.091)	±0.00
1900	5	11	19	56	5151.831	10.63	1491	+0.015	+0.08
"	"	18	20	13	5158.842	9.92	1493	+0.119	-0.04
1901	6	21	14	49	5557.617	9.78	1608	(+0.017)	-0.05
"	"	26	14	49	5562.739	10.11	1610	-0.041	-0.30
"	7	17	15	10	5583.632	10.19	1616	+0.131	+0.41
1902	5	15	17	29	5885.730	9.72	1703	(+0.050)	-0.02
"	"	20	19	45	5890.823	11.12	1705	-0.037	+0.70
"	"	27	16	45	5897.698	10.09	1707	-0.069	-0.18
"	"	"	19	27	5897.810	10.39	1707	+0.043	-0.15
"	7	11	16	51	5942.702	10.41	1720	+0.039	-0.15
"	8	25	12	37	5987.526	10.40	1733	-0.032	-0.05
1903	7	12	15	25	6308.642	10.17	1826	-0.089	±0.00
"	"	"	16	33	6308.690	10.17	1826	-0.041	-0.24
1904	6	11	18	40	6643.778	10.77	1923	+0.059	+0.27
"	"	18	16	59	6650.708	10.29	1925	+0.082	-0.06
"	9	28	12	20	6752.514	9.69	1954	(+0.010)	-0.15
"	"	"	12	32	6752.522	9.73	1954	(+0.019)	-0.10
"	"	"	12	45	6752.531	9.68	1954	(+0.027)	-0.13
"	"	"	12	56	6752.539	9.71	1954	(+0.035)	-0.08
"	"	"	13	8	6752.547	9.72	1954	(+0.043)	-0.05
"	"	"	13	21	6752.556	9.81	1954	(+0.052)	+0.04
"	"	"	13	34	6752.565	9.73	1954	(+0.061)	±0.00

The comparison stars employed are given in Table II. The successive columns give the designation, the catalogue number, the uncorrected rectangular coördinates, expressed in seconds of arc and referred to the variable as an origin, and the adopted photographic magnitude.

TABLE II.
COMPARISON STARS.

Des.	DM.	x	y	Magn.
a	-15° 4908	+ 358.8	-738.0	9.00
b	-15° 4906	- 9.0	-498.0	9.42
c	-15° 4901	- 405.0	+106.2	9.67
d	-15° 4903	- 252.0	-472.8	9.89
e	....	+ 612.0	-682.8	10.49
f	-15° 4914	+1251.0	-363.6	10.77
g	....	- 306.0	-193.8	11.32

Although the time in which the variable can be observed during the present year is short, it is hoped that sufficient observations may be secured to indicate what corrections should be applied to the above formula. An ephemeris is therefore given in Table III. The two columns contain the dates and the times following Greenwich Mean Noon of the primary and secondary minima, respectively. After December 10, the variable will be too near the Sun for observation.

TABLE III.
EPHEMERIS FOR MINIMA.

Prim. Min. 1904.			Second. Min. 1904.			Prim. Min. 1904.			Second. Min. 1904.			Prim. Min. 1904.			Second. Min. 1904.		
d.	h.	m.	d.	h.	m.	d.	h.	m.	d.	h.	m.	d.	h.	m.	d.	h.	m.
Oct. 10	14	11	Oct. 12	7	38	Oct. 31	7	30	Nov. 2	0	56	Nov. 21	0	48	Nov. 22	18	14
" 14	1	4	" 15	18	29	Nov. 3	18	21	" 5	11	48	" 24	11	40	" 26	5	7
" 17	11	57	" 19	5	24	" 7	5	16	" 8	22	41	" 27	22	34	" 29	16	0
" 20	22	50	" 22	16	16	" 10	16	7	" 12	9	34	Dec. 1	9	26	DEC 3	2	53
" 24	9	43	" 26	3	10	" 14	3	2	" 15	20	27	" 4	20	19	" 6	13	46
" 27	20	36	" 29	14	2	" 17	13	54	" 19	7	20	" 8	7	12	" 10	0	39

This variable star is of interest since its light curve is intermediate between that of Y Cygni and Z Herculis. The secondary minimum of the first of these stars is nearly as marked as the primary minimum. The secondary minimum of Z Herculis is barely perceptible, and does not differ from full brightness by much more than a tenth of a magnitude. This difference in the case of -15° 4905 is about three tenths of a magnitude.

EDWARD C. PICKERING.

OCTOBER 7, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 89.

THE NOVEMBER METEORS OF 1904.

VISUAL observations of the Leonids were made on the night of November 14-15, by Professor William H. Pickering, Professor Oliver C. Wendell, Mr. J. A. Dunne, Mr. H. R. Colson, and Mr. Leon Campbell, according to a plan proposed by Professor W. H. Pickering, who has prepared the following report:—

“The night of November 14-15, was very clear at Cambridge, and five observers took part in watching for the Leonids. One observer devoted most of his attention to recording for the others, from two to four of whom were constantly on the watch. Only the eastern half of the sky was covered. A systematic search for Leonids has been made every year at the Harvard Observatory since 1897, with the exception of the year 1903. The largest number of meteors observed in a single night was in 1898, when with the aid of 30 observers, watching the whole sky, 781 were recorded. Three years later in 1901 four observers counted 431 meteors in the eastern half of the sky.

“Owing to the fact that the year does not contain exactly 365 days, and also owing to the gradual advance of the node of the orbit of the meteors, the shower appears about seven hours later each year. After an interval of three to four years we should therefore expect a return of the shower in any given longitude. Counting from 1898 as an origin the shower would not have been due before 1905, but as an unusual number of Leonids was seen last year in England, it was expected that a considerable number might be observed here this year. In this we were not disappointed for 275 meteors were counted, 183 of which were Leonids, a much larger number than had been seen in any previous year save the two already mentioned.

“The search began at twelve o'clock with two observers. Ten meteors were counted in the first 39 minutes, giving an hourly rate of 15. The rate steadily and rapidly increased until in the nine minutes preceding 14^h, with three observers, the meteors were coming at the rate of 134 per hour. A fine shower seemed imminent, but suddenly the rate fell off, averaging only between 50 and 60 for the rest of the night. Apparently the Earth passed out of the denser portion of the swarm at

about 14^h Eastern Standard, or 19^h G.M.T. It is possible that observers to the east of us may have had a fine display this year, and if so, we shall expect more next November.

“Beginning at $14^h 30^m$ an individual account was kept by each observer. The mean of these four accounts was taken, and the mean hourly rate for a single observer thereby determined. At $14^h 40^m$ this rate was 40 meteors per hour. At 15^h it was 36 meteors, at $15^h 20^m$, 29 meteors, at $15^h 40^m$, 28 meteors, at $16^h 00^m$, 26 meteors, at $16^h 20^m$, 25 meteors, at $16^h 40^m$, 24 meteors, and at $17^h 00^m$ it had again risen to 28 meteors.

“Thirty-five meteors were observed of the first magnitude or brighter, none however exceeding magnitude -2 . Generally at the moment of explosion their heads were blue or white, but in at least two cases the color was clearly red or orange, indicating presumably a different chemical constitution.

“The radiant obviously extended over a considerable area, perhaps 8° in diameter, and seemed to be double, many meteors coming from R.A. = $9^h 56^m$, Dec. = $+24^\circ$, and many more from R.A. = $9^h 40^m$, Dec. = $+26^\circ$. WILLIAM H. PICKERING.”

Preparations for photographing the meteors, if large numbers of them appeared, had been made by Mr. King. The following plan was carried out during the latter part of the night, as the radiant point in Leo was below the horizon early in the evening. The 11-inch Draper Telescope was used in photographing the spectra of stars preceding the radiant point of the meteors, and in nearly the same declination. This was done so that, if a bright meteor crossed the field, its spectrum might be photographed, and that the lines might be at right angles to the spectrum. Photographs of the spectra of stars near the radiant point were taken with the 8-inch Draper Telescope, since the slow motion of meteors in that portion of the sky would permit fainter objects to be photographed. The Cooke Anastigmat, and the Ross-Zeiss wide angle lenses were kept at work photographing the region including the radiant point. Photographs of the stars crossing the meridian were also taken all night, as usual, with the transit photometer. Besides these instruments which are regularly in use throughout every clear night, two telescopes, one having a second Cooke Anastigmat with an objective prism, and the other a Morrison wide angle lens, were directed to the zenith.

Notwithstanding the large portion of the sky covered by these photographs, the trail of only one Leonid was found on them. The positions, for 1855, of its two ends are R.A. = $9^h 17^m.2$, Dec. = $+28^\circ 57'$, and R.A. = $9^h 8^m.8$, Dec. = $+29^\circ 52'$. A more careful measure showed that the meteor passed through a point whose position is

R.A. = $9^h 57^m.0$, Dec. = $+24^\circ 14'$. The right ascension was assumed, and the average deviation of the measures of the declination was only $\pm 1'$. It will be seen, therefore, that the radiant point was not only north of that found in Volume XII, No. V, but north of that given by Denning, $+23^\circ.1$. A bright meteor was seen by Mr. King a little before three o'clock, in Leo near the "Sickle," but no sign of it appears on the plates exposed at that time with the Cooke and Ross-Zeiss lenses. It may perhaps, therefore, be inferred from this, that it is at present only possible to photograph meteors which are moving slowly, or are unusually bright. A second, much brighter and longer, meteor trail was photographed early in the evening. The positions, for 1855, of its two ends are R.A. = $4^h 52^m.5$, Dec. = $+0^\circ 52'$, and R.A. = $5^h 10^m.7$, Dec. = $-4^\circ 39'$. It was therefore not a Leonid.

EDWARD C. PICKERING.

NOVEMBER 26, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 90.

105 NEW VARIABLE STARS IN SCORPIUS.

THE investigation of large nebulous regions, described in Circulars Nos. 78, 79, 82, and 86, has been continued by Miss Henrietta S. Leavitt, with the results given in this Circular.

In no respect has the results of photography been more striking than in the revelation of diffused nebulae of vast extent whose faintness renders them almost beyond the reach of visual observation. One of the most remarkable of these extends over many square degrees in the constellations of Scorpius and Ophiuchus. Like the Nebula of Orion, it attaches itself to individual stars, the principal condensation being about the quadruple star, ρ Ophiuchi. The region is marked by a noticeable absence of stars of the fainter magnitudes, and dark lanes can be traced in different directions for a considerable distance beyond the visible nebosity. A cursory examination of a part of this region has led to the discovery of seventy-two new variable stars, besides the known variables, R, S, W, X, Y, RX and RZ Scorp., and No. 1 in the cluster N.G.C. 6093. The position, R. A. = $16^h 23^m 39^s$, Dec. = $-19^\circ 7'.1$ (1900), does not differ greatly from R. A. = $16^h 23^m 49^s$, Dec. = $-19^\circ 13'.3$ (1900), which is that given for Y Scorp. by its discoverer, Dr. Peters. As Hartwig states that the position of Y Scorp. is uncertain, it is assumed that the two positions refer to the same object. Thirty-three plates were examined. Of these, twenty-six were taken with the 24-inch Bruce Telescope, with exposures of from 60 to 273 minutes, and seven were taken with the 8-inch Bache Telescope, with exposures of from 45 to 150 minutes. In the region extending in right ascension from about $16^h 0^m$ to $16^h 20^m$, and in declination from about -18° to -23° , it is improbable that any large number of variables, which at maximum are brighter than the fourteenth magnitude, have been overlooked. The region extending in right ascension from about $16^h 25^m$ to $16^h 45^m$, and in declination from about -25° to -30° , has also been fairly well covered, especially in the following portion. A few variables outside of the above limits are in regions for which there was but little material available for examination.

In Table I, the successive columns give a number for reference, the right ascension and declination for 1900, the brightest and faintest observed magnitudes, according to a provisional scale, and the range.

TABLE I.
VARIABLE STARS IN SCORPIUS.

No.	R. A. 1900.			Dec. 1900.	Br.	Ft.	R.	No.	R. A. 1900.			Dec. 1900.	Br.	Ft.	R.
	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>					<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>			
1	15	57	34	-23 18.4	12.8	<15.0	2.2	37	16	25	28	-27 41.7	12.2	<13.6	1.4
2	16	1	6	-21 54.0	13.5	14.4	0.9	38	16	26	40	-26 10.4	11.8	<15.0	3.2
3	16	1	10	-23 24.0	12.9	14.0	1.1	39	16	27	13	-25 58.6	11.8	13.7	1.9
4	16	1	45	-23 2.6	11.3	14.5	3.2	40	16	27	38	-26 32.2	12.2	14.8	2.6
5	16	1	52	-23 47.6	12.3	13.9	1.6	41	16	28	2	-26 24.2	11.7	13.1	1.4
6	16	2	35	-21 49.1	12.4	14.2	1.8	42	16	29	4	-26 16.5	11.2	15.0	3.8
7	16	3	42	-21 37.9	13.0	13.6	0.6	43	16	30	41	-29 31.8	12.8	<15.0	2.2
8	16	4	18	-22 27.3	11.8	13.3	1.5	44	16	30	52	-27 6.5	12.2	<15.0	2.8
9	16	4	27	-23 50.4	11.2	13.1	1.9	45	16	31	12	-27 53.6	13.7	<15.0	1.3
10	16	4	52	-22 48.2	10.7	14.8	4.1	46	16	31	32	-29 6.9	13.2	14.2	1.0
11	16	6	7	-19 40.3	13.0	14.2	1.2	47	16	31	58	-28 22.0	10.5	<15.0	4.5
12	16	6	36	-20 40.4	11.4	12.2	0.8	48	16	32	37	-27 49.4	13.5	<15.0	1.5
13	16	8	46	-21 27.1	11.2	14.3	3.1	49	16	34	48	-27 15.9	10.9	<14.5	3.6
14	16	9	8	-21 30.6	11.1	12.1	1.0	50	16	36	37	-24 34.2	10.5	12.0	1.5
15	16	9	37	-24 46.0	12.3	15.5	3.2	51	16	38	16	-27 49.9	13.1	14.1	1.0
16	16	9	38	-22 28.1	11.2	12.8	1.6	52	16	38	42	-24 55.6	11.2	12.8	1.6
17	16	10	10	-23 21.3	12.3	13.7	1.4	53	16	38	46	-28 43.2	13.6	14.5	0.9
18	16	10	58	-21 24.3	12.9	13.6	0.7	54	16	39	1	-26 41.5	12.6	13.8	1.2
19	16	12	11	-21 34.6	13.4	<15.0	1.6	55	16	39	30	-28 1.7	10.9	13.0	2.1
20	16	12	22	-20 57.4	12.4	14.2	1.8	56	16	39	43	-29 31.9	13.6	14.9	1.3
21	16	13	28	-22 7.0	11.8	<15.0	3.2	57	16	40	23	-27 12.4	10.7	14.8	4.1
22	16	13	42	-23 10.0	10.8	12.3	1.5	58	16	40	25	-29 57.5	13.8	<14.8	1.0
23	16	14	36	-23 0.2	12.9	14.1	1.2	59	16	40	29	-27 56.8	13.6	<14.8	1.2
24	16	15	2	-21 17.4	11.7	12.4	0.7	60	16	41	6	-30 15.7	12.5	13.5	1.0
25	16	15	32	-21 53.1	11.6	12.3	0.7	61	16	41	8	-28 1.9	14.2	14.8	0.6
26	16	15	48	-22 39.1	13.6	14.7	1.1	62	16	41	15	-29 25.3	13.9	14.5	0.6
27	16	16	42	-20 44.3	13.3	14.7	1.4	63	16	42	12	-29 56.9	12.8	13.8	1.0
28	16	18	14	-22 16.0	12.3	12.8	0.5	64	16	43	5	-27 2.6	13.0	<15.0	2.0
29	16	19	21	-24 15.9	12.5	12.9	0.4	65	16	43	36	-27 16.2	13.7	14.9	1.2
30	16	20	43	-22 5.6	12.9	<15.5	2.6	66	16	43	36	-29 24.1	11.3	11.8	0.5
31	16	20	50	-22 0.3	13.0	13.8	0.8	67	16	43	56	-28 17.2	10.9	<14.7	3.8
32	16	21	1	-31 4.7	10.6	<14.7	4.1	68	16	44	4	-27 49.6	13.0	14.0	1.0
33	16	22	6	-21 22.1	12.1	13.0	0.9	69	16	44	9	-28 1.2	13.6	14.5	0.9
34	16	22	21	-21 32.8	12.0	12.9	0.9	70	16	44	17	-25 23.4	10.9	<15.0	4.1
35	16	23	8	-29 48.3	13.8	14.7	0.9	71	16	44	38	-27 47.6	13.8	14.8	1.0
36	16	23	13	-20 1.0	12.4	13.5	1.1	72	16	46	18	-28 22.8	12.2	<15.0	2.8

REMARKS.

No. 10. This star is C. DM. -22° 11391.	No. 39. The northern and preceding of two stars.
No. 29. In a strongly nebulous region. Variation well seen, though small.	No. 49. This star is C. DM. -27° 11069.
No. 36. The variation, although well seen, is less marked than the estimated magnitudes would indicate. The variable is near the edge of the plates, and difficult to observe.	No. 50. This star is C. DM. -24° 12774.
No. 38. A star of about the magnitude 14.5 precedes the variable about $1^{\circ}.5$, and is south of it about $0^{\circ}.8$.	No. 55. The following of two stars.
	No. 66. Variation well seen, though small.
	No. 69. The central star of a line of three having nearly the same declination.
	No. 72. A star of the fifteenth magnitude is about $2'$ following, and $0^{\circ}.7$ north.

Nos. 7, 11, 17, 18, 26, 27, and 62, are apparently variable stars of short period, but the majority of the others will perhaps be found to have long periods. These variables are, in general, brighter at maximum than those announced in Circulars Nos. 78, 79, and 82. The range of variation is greater, twenty-one showing changes of two magnitudes or more. It cannot be determined whether many of these variable stars are directly connected with the nebula, as only one of them, No. 29, is in a strongly nebulous region. Very few faint stars are seen in such regions, excepting on one plate, which was exposed for 273 minutes.

An open and rather irregular globular cluster, Messier 4 (N.G.C. 6121), is situated at the edge of the nebula, near α Scorpii. Two variable stars were discovered in it during the general examination of the region, and seven others were noticed while these were being observed. This led to a careful examination of the cluster, by Professor Bailey's method, as described in Volume XXXVIII of the Annals. Eight plates, four of which were taken with the 24-inch Bruce Telescope, and four with the 8-inch Bache Telescope, were used. Within a radius of fifteen minutes from the centre of the cluster, in an area of 706 square minutes, 334 stars were counted, and 32 variables found besides No. 33, which is seventeen minutes from the centre. Five other stars are suspected, and will probably be confirmed as variable when additional photographs can be examined. These variables and several catalogue stars are given in Table II. The first two columns give the designation and the number in the Cordoba Durchmusterung. In the third and fourth columns are given the coördinates referred to the assumed centre of the cluster, and expressed in seconds of arc. They depend upon eye estimates, but are probably correct within three seconds of arc. No correction has been made for the scale and orientation of the enlargement used. These, however, may be determined from the catalogue stars. The last three columns give the brightest and faintest observed magnitudes, and the range.

TABLE II.
VARIABLE STARS IN N.G.C. 6121.

Des.	Cat. No.	α	y	Br.	Ft.	R.	Des.	Cat. No.	α	y	Br.	Ft.	R.
A	-26° 11305	"	"	..	..	..	15	..	..	"	"	..	..
B	-26° 11310	-379	-1053	..	..	..	16	..	..	-32	+436	12.7	13.7
C	-26° 11316	-152	+564	..	..	..	17	..	..	-29	+69	12.8	13.8
D	-25° 11495	+61	-204	..	..	..	18	..	..	-8	+20	13.2	13.7
E	-26° 11329	+184	+924	..	..	..	19	..	..	+4	+27	13.0	13.7
1	..	+881	-1029	..	..	..	20	..	..	+11	+358	12.6	13.6
2	..	-281	+42	13.0	13.5	0.5	21	..	..	+13	-63	13.0	13.4
3	..	-248	-195	13.0	13.9	0.9	22	..	..	+19	-4	13.0	13.7
4	-26° 11309	-208	-507	12.6	13.6	1.0	23	..	..	+34	+80	13.1	13.7
5	..	-185	-340	10.7	12.0	1.3	24	..	..	+38	-26	12.9	13.4
6	..	-185	-93	13.1	13.4	0.3	25	..	..	+49	+48	12.4	13.9
7	..	-115	+318	13.1	13.5	0.4	26	..	..	+70	+70	12.9	13.6
8	..	-113	+231	12.9	13.8	0.9	27	..	..	+94	-72	12.1	13.7
9	..	-110	+111	13.0	13.7	0.7	28	..	..	+118	+255	12.7	13.7
10	..	-104	+105	13.1	13.7	0.6	29	..	..	+259	+84	12.9	13.5
11	..	-68	+159	12.7	13.7	1.0	30	..	..	+326	+598	12.4	13.7
12	..	-64	-297	12.0	13.4	1.4	31	..	..	+340	-69	13.0	13.5
13	..	-53	-207	12.7	13.9	1.2	32	..	..	+353	+45	11.9	13.5
14	..	-47	+270	12.0	12.6	0.6	33	..	..	+746	-40	12.6	13.5
	..	-47	-244	13.1	14.2	1.1		..	..	+805	+630	12.5	13.2

EDWARD C. PICKERING.

DECEMBER 8, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 91

SIXTEEN NEW VARIABLE STARS IN SAGITTARIUS.

THE Trifid Nebula is near the centre of a large number of the plates taken for the study of Phoebe, the Ninth Satellite of Saturn. A careful search for variable stars in this interesting region has been made by Miss Leavitt. Seventeen plates taken with the 24-inch Bruce Telescope, and having exposures of from one to three hours, have been examined. The extent of the region covered has been increased by the use of fourteen plates, taken with the 8-inch Bache Telescope, and having exposures of from forty-five to sixty minutes. There seems to be no evidence that variable stars are present in large numbers in this region.

In the table the successive columns give a current number, the right ascension for 1900, the declination for 1900, the brightest magnitude, the faintest magnitude, and the range of variation.

VARIABLE STARS IN SAGITTARIUS.

No.	R. A. 1900.			Dec. 1900.	Br.	Ft.	R.	No.	R. A. 1900.			Dec. 1900.	Br.	Ft.	R.		
	<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>	<i>'</i>				<i>h.</i>	<i>m.</i>	<i>s.</i>	<i>°</i>	<i>'</i>				
1	17	46	3	-22	35.3	12.0	14.7	2.7	9	18	2	1	-22	14.1	9.5	11.9	2.4
2	17	47	8	-21	44.6	12.2	14.7	2.5	10	18	2	20	-22	57.3	13.7	14.6	0.9
3	17	49	6	-21	43.5	12.6	13.9	1.3	11	18	2	24	-23	4.8	14.0	15.1	1.1
4	17	51	8	-19	19.5	10.5	<14.5	4.0	12	18	6	7	-20	43.4	10.9	12.8	1.9
5	17	54	22	-21	7.7	12.1	13.6	1.5	13	18	8	44	-29	44.2	10.6	12.1	1.5
6	17	57	16	-26	28.6	11.0	12.3	1.3	14	18	16	49	-27	28.4	11.5	<13.0	1.5
7	17	58	24	-22	57.5	13.4	14.5	1.1	15	18	17	26	-18	37.4	10.4	11.4	1.0
8	17	58	45	-22	44.1	10.9	12.0	1.1	16	18	17	46	-30	38.8	10.6	12.0	1.4

REMARKS.

5. Probably of the Algol type. Brightness uniform on twenty-two out of twenty-six plates examined.
7. Probably of the Algol type. Brightness uniform on eighteen out of twenty plates examined.
9. This is $-22^{\circ} 4575$, and the preceding of two stars.
11. The preceding of two stars. Probably of the Algol type. Brightness uniform on eighteen out of twenty plates examined.
13. This is C. DM. $-29^{\circ} 14717$.
16. This is C. DM. $-30^{\circ} 15642$.

The total number of new variables discovered by Miss Leavitt and announced in Circulars Nos. 78, 79, 82, 86, 90, and 91, is 410.

EDWARD C. PICKERING.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 92.

STARS HAVING PECULIAR SPECTRA.

AN examination of the photographs of the Henry Draper Memorial has led to the discovery, by Mrs. Fleming, of a number of variable stars and objects having peculiar spectra, in addition to those previously published. A list of these has been compiled by Mrs. Fleming, and is given below, together with a number of variables already known, for which the spectrum has recently been determined, and two additional objects found by other observers, as stated in the remarks following the table. The constellation and catalogue designation are given in the first two columns. The approximate right ascension and declination for 1900, and the catalogue magnitude, except in the case of variables, are given in the third, fourth, and fifth columns. The class of spectrum and a brief description of the object are given in the sixth and seventh columns. The designations for stars north of declination -23° are taken from the Bonn Durchmusterung, for stars between declinations -23° and -52° the Cordoba Durchmusterung is used, and for stars south of declination -52° the Cape Photographic Durchmusterung is used. Each of the new variables has been confirmed independently by a second observer. Additional information regarding several of these objects will be found in the remarks following the table.

PECULIAR SPECTRA.

Constellation.	DM. No.	R. A. 1900.	Dec. 1900.	Magn.	Spectrum.	Description.
		<i>h. m.</i>	<i>° '</i>			
Andromeda	.....	0 10.8	+46 27	..	Md	Variable. X Andromedae.
Andromeda	+38° 315	1 33.7	+38 50	..	Md	Variable. Y Andromedae.
Taurus	.....	4 32.8	+8 9	..	Md	Variable.
Orion	+7° 768	4 53.6	+7 59	..	Md?	Variable. R Orionis.
Orion	+4° 949	5 25.1	+4 7	..	K 5 M	Variable. Peculiar.
Camelopardalus	.....	5 49.4	+74 30	..	Md	Variable. V Camelopardali.
Monoceros	-11° 1460	6 16.8	-11 44	5.9	B Pec.	H β bright.
Monoceros	-2° 1581	6 17.7	-2 9	..	Md	Variable. V Monocerotis.
Ursa Major	.....	8 33.9	+50 29	..	Md	Variable. - Ursae Majoris.
Ursa Major	+50° 1603	8 56.2	+50 29	9.2	N	Peculiar.

Constellation.	DM. No.	R. A. 1900.		Dec. 1900.	Magn.	Spectrum.	Description.
		<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>		
Virgo	- 5° 3456	12	9.5	- 5	29	..	Md Variable. T Virginis.
Bootes	+ 14° 2700	14	1.7	+ 13	58	..	Md? Variable. Z Bootis.
Libra	- 2° 3939	14	58.8	- 2	28	9.6	N Peculiar.
Norma	- 54° 6651	15	36.4	- 54	40	..	Md Variable. T Normae.
Lyra	+ 36° 3066	18	11.5	+ 36	38	..	Md Variable. W Lyrae.
Heracles	.....	18	16.7	+ 31	41	..	Md Variable.
Sagittarius	.....	18	29.5	- 31	47	..	Pec. Dark bands.
Lyra	.....	18	42.2	+ 43	32	..	Md Variable. RW Lyrae.
Sagittarius	- 29° 15574	18	52.4	- 29	38	8.9	Pec. Dark bands.
Sagittarius	.....	19	8.5	- 19	0	..	 Variable.
Sagittarius	- 33° 14076	19	10.0	- 33	42	..	Pec.!! Variable. RV Sagittarii.
Sagittarius	.....	19	13.8	- 21	7	..	Md Variable. Z Sagittarii.
Cygnus	+ 49° 3225	20	9.8	+ 49	9	..	Mc 5 d Variable.
Cygnus	+ 29° 4231	20	50.9	+ 30	2	..	Md Variable. UX Cygni.
Cygnus	+ 39° 4368	20	51.6	+ 39	55	7.2	Cont.
Cepheus	+ 64° 1527	21	17.3	+ 64	27	5.5	B Pec. H β bright.
Pegasus	+ 24° 4462	21	40.0	+ 24	33	..	Md Variable. RR Pegasi.
Cepheus	+ 61° 2246	22	2.1	+ 61	48	6.0	Pec.
Cepheus	+ 58° 2402	22	8.1	+ 58	56	5.6	Pec. λ Cephei.
Cetus	- 15° 6531	23	57.0	- 15	14	..	Md Variable. W Ceti.
Cassiopeia	+ 54° 3103	23	58.3	+ 54	60	7.9	Pec. H β bright.

REMARKS.

- h. m.*
 4 32.8. This star varies probably more than three magnitudes, being as bright as the magnitude 9.0 on one of the plates examined, and fainter than 12 on two plates.
 5 25.1. The spectrum of this star is between Classes K and M, and shows a bright line of slightly shorter wavelength than H δ . The plates examined show a variation of about 0.7 magnitude, and, as in the case of the other stars, the variation has been confirmed by a second observer.
 6 16.8. On a plate taken on October 16, 1904, with the 11-inch Draper telescope, the hydrogen line H β is bright. H γ is very faint and double, and the remaining lines of hydrogen and those of helium appear to be double. This is probably a spectroscopic binary. The spectrum of -11° 1478, which is also on this plate, shows well defined single lines.
 8 56.2. This spectrum extends beyond H ϵ , having, besides the usual dark band in fourth type spectra, a second strong band near wavelength H δ , and a third, between H δ and H ϵ .
 14 58.8. This spectrum shows the same peculiarities as that of the star, R.A. 8^h 56^m.2.
- h. m.*
 18 29.5. This spectrum has a broad dark band which extends from about λ 465 to 471, and is of the same type as C.D.M. — 47° 6614, described in Circular No. 76.
 18 52.4. This spectrum is already known as peculiar, but is inserted in the table in order to describe it as belonging to the same type as C.D.M. — 47° 6614, described in Circular No. 76.
 19 8.5. This star was the comparison star "o" in the sequence selected for RW and RX Sagittarii, and during the observations of these stars the variation in this star was discovered by Miss S. E. Breslin.
 20 9.8. An examination of 16 chart plates shows a variation of about a magnitude in this star.
 20 51.6. On a plate taken on September 15, 1904, the spectrum of this star is continuous, and fails to show any trace of lines, although the lines in other spectra are well defined. On some of the other plates the hydrogen lines show faintly, even with the spectrum not so well defined.
 21 17.3. On a plate taken on October 16, 1904, with the 11-inch Draper telescope, the hydrogen line H β is bright, the other lines are broad, and the spectrum has the same general appearance as that of the star,

- | | |
|---|---|
| <p><i>h. m.</i>
R.A. $6^h 16^m.8$, although the lines in this spectrum do not appear double.</p> <p>22 8.1. λ Cephei. The star ζ Puppis has a spectrum that heretofore has been regarded as unique. It contains, besides the usual series of hydrogen lines, a second rythmical series also probably due to hydrogen, and only a few other lines. The southern declination of this star has rendered it difficult to study its spectrum at the</p> | <p><i>h. m.</i>
great observatories in Europe, or in the United States. The spectrum of the northern star, λ Cephei, was found by the writer to be identical with that of ζ Puppis.</p> <p>23 58.3. The hydrogen line $H\beta$ is bright and superposed upon a broad dark line. The lines $H\gamma$, $H\delta$, and $H\epsilon$ are narrow, and two other narrow lines having the approximate wavelengths 416 and 420 are also present.</p> |
|---|---|

The variability of C.P.D.—73° 1134, R.A. = $13^h 13^m.5$, Dec. = $-73^\circ 55'$ (1900), suspected by Kapteyn, has been discovered independently by Miss L. D. Wells, and shows a range of about a magnitude and a half.

EDWARD C. PICKERING.

DECEMBER 21, 1904.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 93.

THE 24-INCH REFLECTING TELESCOPE.

ONE of the most important results obtained with the Anonymous Fund of 1902 has been the construction of the 24-inch Reflecting Telescope. The mirror was made by Messrs. Alvan Clark & Sons, and the mounting has been designed and constructed by Mr. Willard P. Gerrish of this Observatory. Although the mounting is not completed, yet it is so far advanced that the telescope can be used for visual work, and is giving excellent results in determining the light of faint stars. Accordingly, measures have been made by Mr. Leon Campbell of three of the variable stars discovered by Miss Leavitt, Nos. 91, 93, and 94, near the Nebula of Orion, and announced in Circular No. 86. The dates of observation, the magnitudes derived for No. 91 from observations by the writer with the 12-inch Meridian Photometer, and the magnitudes of Nos. 91, 93, and 94, as determined with the 24-inch, are given in the successive columns of Table I.

TABLE I.
OBSERVATIONS OF VARIABLES.

Date. 1905.	12-inch. 91	24-inch.			Date. 1905.	12-inch. 91	24-inch.		
		91	93	94			91	93	94
January 28	..	10.8	13.0	13.5	February 18	10.8	..	..	..
" 30	..	10.4	13.0	13.5	" 21	10.9	10.9	..	..
" 31	..	10.7	12.9	13.6	" 23	..	11.1	..	..
February 2	..	10.8	12.8	13.6	" 25	11.7	11.4	r	12.4
" 3	..	10.9	12.6	13.6	" 27	11.4	11.5	13.1	12.7
" 4	..	11.2	12.5	r	" 28	11.5	11.3	12.9	12.8
" 7	..	11.7	12.7	13.4	March 1	..	11.1	12.5	12.9
" 11	..	10.6	12.9	13.0	" 2	11.0	10.9	12.9	12.7
" 13	10.8	10.6	..	..	" 3	10.8	10.7	13.0	12.8
" 14	10.8	10.8	..	..	" 4	..	10.7	12.7	13.0
" 16	10.9	10.7	..	..	" 11	..	11.0	14.0	12.4

While the variability of all three stars is thus confirmed, the absolute magnitudes of the fainter stars are uncertain. On February 4, 1905, No. 94 was not visible, and was certainly fainter than the magnitude 13.6. On February 22, No. 93 was certainly fainter than 13.2. The Moon prevented observations of Nos. 93 and 94, from February 13 to February 23. As these stars are within 40" of each other, and are usually alternately bright and faint, it seemed probable that the period was the same for both, and that some connection existed between them. On one photograph, however, both stars appear bright, so probably the periods differ slightly.

EDWARD C. PICKERING.

MARCH 13, 1905.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 94.

VARIABILITY OF EUNOMIA (15).

A VARIATION in the light of the asteroid Eunomia (15) has been established by Professor Wendell, from observations made with the photometer having achromatic prisms, attached to the 15-inch telescope of this Observatory. The first observations were made on March 15, 1905, or J. D. 2,416,920. Eunomia was then near its second stationary point, so that it could be compared with the same star, +13° 1875, magn. 9.0, until April 1, 1905, J. D. 2,416,937, inclusive. Owing to its increasing distance, both from the Sun and the Earth, its mean brightness

TABLE I.
OBSERVATIONS OF EUNOMIA (15).

J. D.	Diff.	E.	Phase.	Corr.	M.	O—C.	J. D.	Diff.	E.	Phase.	Corr.	M.	O—C.
6920.661	0.92	4	0.038	0.77	+15	-.02	6934.617	1.39	114	0.057	1.03	+36	-.01
6920.670	1.06	"	0.047	"	+.29	+.02	6934.631	1.41	"	0.071	"	+38	+.02
6921.608	0.82	11	0.098	0.69	+13	.00	6934.651	1.17	"	0.091	"	+14	-.05
6928.655	1.23	67	0.050	0.93	+.30	-.01	6936.536	1.40	129	0.076	1.06	+34	+.02
6928.667	1.34	"	0.062	"	+.41	+.02	6936.548	1.30	"	0.088	"	+.24	+.02
6928.678	1.26	"	0.073	"	+.33	-.01	6936.562	1.15	"	0.102	"	+.09	-.02
6932.578	1.19	98	0.045	0.93	+.26	+.01	6936.575	1.08	"	0.115	"	+.02	.00
6932.591	1.31	"	0.058	"	+.38	.00	6936.589	1.02	130	0.002	"	-.04	-.04
6932.606	1.31	"	0.073	"	+.38	+.03	6937.524	1.48	137	0.050	1.11	+.37	+.06
6932.620	1.16	"	0.087	"	+.23	.00	6937.536	1.49	"	0.062	"	+38	-.01
6932.633	1.03	"	0.100	"	+.10	-.02	6937.552	1.39	"	0.078	"	+.28	-.02
6932.648	0.97	"	0.115	"	+.04	+.02	6937.569	1.28	"	0.095	"	+.17	+.01
6932.659	0.92	"	0.126	"	-.01	-.01	6937.587	1.14	"	0.113	"	+.03	.00
6934.542	1.05	113	0.109	1.03	+.02	-.02	6937.604	1.10	138	0.003	"	-.01	-.02
6934.555	1.02	"	0.122	"	-.01	-.01	6937.625	1.16	"	0.024	"	+.05	-.02
6934.568	1.04	114	0.008	"	+.01	.00	6937.638	1.26	"	0.037	"	+.15	-.01
6934.583	1.10	"	0.023	"	+.07	.00	6937.648	1.38	"	0.047	"	+.27	.00
6934.603	1.29	"	0.043	"	+.26	+.04	6937.661	1.50	"	0.060	"	+.39	.00

diminished a third of a magnitude during this time. Each observation consisted of four sets, of four settings each. The mean of the times, expressed in Julian Days and decimals, is given in the first column of Table I. The observed difference in magnitude of Eunomia and the comparison star is given in the second column. It appeared from a study of these observations that the times of maximum could be expressed by the formula $J. D. 2416920.116 + 0.1267 E$. The values of E and of the phase are given in the third and fourth columns. It appeared from the observations that Eunomia, when at maximum on the first day, was about 0.77 magnitudes fainter than the comparison star, and 1.11 on the last day. The exact value for each day is given in the fifth column, and was found by assuming, from an inspection of the curves, the approximate values, and applying a small correction dependent on the condition that the sum of the positive and negative residuals from the light curve should be equal. It will be noticed that the diminution in the mean brightness of Eunomia, which is thus indicated, is not perfectly uniform. This may be due in part to the variations, if any, in the comparison star or in the mean light of Eunomia. Subtracting the numbers in the fifth column from those in the second, gives the observed brightness, compared with the maximum brightness after correcting for the varying mean brightness.

TABLE II.
LIGHT CURVE.

Phase.	Magn.
.00	.00
.01	.02
.02	.05
.03	.11
.04	.19
.05	.31
.06	.39
.07	.36
.08	.28
.09	.20
.10	.11
.11	.04
.12	.01

This is given in the sixth column. The seventh column contains the residual found by subtracting the magnitude, according to the light curve represented in Table II, from the results given in the sixth column. It will be noticed that the average value of these residuals is only ± 0.016 .

The form of light curve is shown in Table II, the corresponding phases and magnitudes being given in the first and second columns.

It will be noticed that the period, $0^d.1267$, does not differ greatly from that of Iris (7), $0^d.1295$, and that in both cases it is still doubtful whether this period should be doubled. A careful series of observations by Mr. Leon Campbell, using Argelander's method, seems to indicate that in the case of Eunomia the period should perhaps be doubled, and that the intervals between the successive minima are alternately long and short. It is difficult to see on theoretical grounds how this can be the case, or how the alternate maxima or minima

can differ in intensity, if the variation in light is wholly due to the unsymmetrical form of the body.

It is unfortunate that no easy means exists for observing and following known asteroids, except when near opposition. Table III contains the approximate positions of Eunomia on the dates given in the first column. The right ascensions and declinations for 1855 are given in the second and third columns. This

TABLE III.
EPIHEMERIS OF EUNOMIA.

J. D.	R. A. 1855.		Dec. 1855.	
	<i>h.</i>	<i>m.</i>	<i>°</i>	<i>'</i>
6920	8	7.6	+13	15
6925	8	7.5	+13	12
6930	8	9.0	+13	7
6935	8	9.1	+13	1
6940	8	11.0	+12	53
6945	8	13.4	+12	44
6950	8	16.7	+12	33

is the most convenient epoch both for visual and for photographic observations, since the positions may be compared directly with those of adjacent stars in the Durchmusterung.

EDWARD C. PICKERING.

APRIL 8, 1905.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 95.

BRIGHTNESS OF JUPITER'S SATELLITES.

For many years the four brighter satellites of Jupiter have been suspected of variability. Each of these satellites appears faint when very near Jupiter. This is a subjective effect, and is always produced when a bright object is near a stellar image. It is very marked before or after the occultation of a bright star or planet by the Moon. Various other defects of the eye render the results of direct comparison of the satellites uncertain. A series of measures of the satellites has accordingly been made by Professor Wendell, with the polarizing photometer attached to the 15-inch Telescope of this Observatory and described in the second paragraph of Circular No. 25. The plan proposed was that each satellite should be compared with the other three on three nights, and that two measures, each consisting of four sets of four settings each, should be made each night. By reversing the prism and images, and placing the latter equidistant from Jupiter, known sources of error were eliminated. The total number of settings required was 576, but unfortunately the approach of Jupiter to the Sun rendered it impossible to secure all the desired measures. The results are given in Table I, the six possible combinations being given in the six lines. The order of brightness of the satellites was always, III, I, II and IV. The brighter of the two satellites compared is given in the first column, the fainter in the second. The times of observation, expressed in Julian Days and decimals, omitting the three left-hand figures 241, are given in the third column. The mean of all the measures is given in the fourth column, and the residuals from the mean, expressed in hundredths of a magnitude, are given for the different days in the next three columns. A least square solution, from the results in the fourth column, gave the values 0.42, 0.16, and 0.64, for the three intervals, III to I, I to II, and II to IV, respectively. The computed values of all the intervals are given in the eighth column, and the residuals found by subtracting them from the observed values given in the third column are given in the ninth column. In 1877 and 1878, measures of the satellites of Jupiter were made here and are described in Volume XI, Chapter VIII. The difference in magnitude there

found between Jupiter and the four satellites, and given on page 246 in the second column of Table XLVIII, is for Satellite I. 8.13; for II, 8.27; for III, 7.76; for IV, 8.89. The corresponding differences between the magnitudes of the satellites are given in the tenth column of Table I. Thus, for Satellites I and III, we have, $8.13 - 7.76 = 0.37$, which is entered in the first line of the column. The differences between these and the computed values are found by subtracting the values in the eighth column from those in the tenth and are entered in the eleventh column. It will be noticed that all of these differences are negative, that is, that the interval between the satellites appeared to be less in the earlier than in the later observations. Correcting this difference, for which there is no obvious explanation, by multiplying the results in the tenth column by 1.08 and subtracting the products from the computed values given in the eighth column, we have the residuals given in the twelfth column.

TABLE I.
RESULTS OF OBSERVATIONS.

Br.	Ft.	Julian Days.	Mean.	I.	II.	III.	C.	O—C.	XI.	Res.	Res.
III	I	6900.592, 6907.524	0.42	00	00,00		0.42	.00	0.37	-.05	-.02
III	II	6904.538, 6906.528, 6918.542	0.62	00,00	00,04	01,03	0.58	+.04	0.51	-.07	-.03
III	IV	6905.526, 6911.524, 6915.522	1.18	00,01	02,02	01	1.22	-.04	1.13	-.09	.00
I	II	6902.528, 6909.533, 6916.547	0.14	05,05	05,00,00	02	0.16	-.02	0.14	-.02	-.01
I	IV	6922.518	0.83	00,00			0.80	+.03	0.76	-.04	+.02
II	IV	6911.549, 6920.520, 6928.518	0.66	08	04,06	02	0.64	+.02	0.62	-.02	+.03

The average value of the 26 residuals in the fifth, sixth and seventh columns is ± 0.020 , and of the 6 residuals in the eighth column, is ± 0.025 . The average value of the residuals in the twelfth column is even smaller, ± 0.018 . There appears therefore to be no evidence of variation during the time that these measures were made.

EDWARD C. PICKERING.

APRIL 11, 1905.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 96.

843 NEW VARIABLE STARS IN THE SMALL MAGELLANIC CLOUD.

IN Circular No. 79, announcement was made of the discovery of 57 new variable stars in the Small Magellanic Cloud. In order to provide material for the study of their light curves, sixteen excellent photographs, having exposures of from two to four hours, were taken last autumn at Arequipa, with the 24-inch Bruce Telescope. These plates reached Cambridge in January, and an examination of them by Miss Leavitt led to the surprising discovery that hundreds of variable stars were present in this region, the small number found in her earlier examination being due to the unsatisfactory quality of many of the plates. The determination of the positions, elements, and light curves of this large number of variables is now in progress, and will be published in the *Annals* as soon as it is completed. It does not, therefore, seem advisable to duplicate the publication of the positions of this long list of variables, especially as they can only be observed by the help of photographs on which they are marked, and these can be furnished at any time to astronomers who will undertake to observe them. As some time must elapse before the full publication is made, it may be worth while to give some of the general conclusions which have already been reached.

The total number of new variables discovered in this region in the present research is 900, including the 57 announced in Circular No. 79. There are also 64 other stars suspected of variation.

To study the distribution of the variables, the region of about six by seven degrees, covered by the plates, has been divided into squares which measure approximately half a degree on a side. The centre adopted, R. A. = $0^h 51^m$, Dec. = $-73^\circ.4$ (1900), is not far from the centre of the Small Magellanic Cloud, which extends diagonally in a direction from north-east to south-west. The limits of the region containing the variables are more sharply defined, and are closer to the central line of the most densely crowded portion on the preceding than on the following side.

Table I contains the number of variables in each of the squares described above. Twenty-three known variables are included, namely, 005475 in the Provisional

Catalogue, Annals XLVIII. No. 3, eight variables in the cluster N. G. C. 104, 47 Tucanae, and fourteen in N. G. C. 362. No. 52, in Circular No. 79, is outside the region covered by the table, which includes 922 variables. The headings of the columns give the limits in right ascension of the squares, distances being measured from the centre of the region. The first column of the table gives the limits in declination of the squares, and the following columns give the corresponding numbers of variables.

TABLE I.
THE SMALL MAGELLANIC CLOUD.

Region.	+3°.0 to +3°.5	+2°.5 to +3°.0	+2°.0 to +2°.5	+1°.5 to +2°.0	+1°.0 to +1°.5	+0°.5 to +1°.0	0°.0 to +0°.5	-0°.5 to 0°.0	-1°.0 to -0°.5	-1°.5 to -1°.0	-2°.0 to -1°.5	-2°.5 to -2°.0	-3°.0 to -2°.5	-3°.5 to -3°.0
+2.5 to +3.0	..	..	..	..	..	1	..	1	..	..	..	..	..	..
+2.0 " +2.5	..	..	..	..	..	..	..	1	..	1	..	..	..	..
+1.5 " +2.0	..	..	..	..	19	8	1	3	..	..	..	..	..	..
+1.0 " +1.5	..	..	..	10	34	18	17	4	..	..	..	..	..	..
+0.5 " +1.0	..	..	..	3	19	33	37	21	..	1	2	13	..	..
0.0 " +0.5	..	1	1	3	37	48	49	38	14	1	..	..	..	1
-0.5 " 0.0	..	..	1	3	23	43	72	64	46	7	1	..	..	..
-1.0 " -0.5	..	2	1	3	6	36	43	56	22	12	4	..	..	..
-1.5 " -1.0	..	1	3	1	3	3	5	3	2	9	2	..	..	..
-2.0 " -1.5	..	..	..	1	1	..	..	..	..	..	..	..	..	..
-2.5 " -2.0	1	..	..	..	..	..	1	..	..	..	..	..	..	..
-3.0 " -2.5	..	..	1	..	..	..	..	..	..	..	..	..	..	..

Nearly all the variables are found strictly within the limits of the Small Magellanic Cloud. Few have been found at a greater distance than a degree and a half from the centre, excepting in the clusters 47 Tucanae and N. G. C. 362. The more sharply defined limits of the preceding side of the region are seen also in the distribution of the variables.

Several examples of variability are shown in Figures 1 and 2, which are enlarged six times from the original photographs. The area represented is $12'.0$ square, on a scale of $10'' = 0.1$ cm., and the position of the centre for 1900 is R. A. = $0^h 55^m.9$, Dec. = $-73^\circ 55'$. Figure 1 is an enlargement from Plate A 3393, taken November 10, 1898, exposure 300 minutes, and Figure 2 is from Plate A 6981, taken September 30, 1904, exposure 240 minutes. All the variables in the region are marked on the latter, while on the former three stars are marked in which the changes are

well seen on this pair of plates. According to the scale used in Circular No. 79, the two conspicuous variables in the lower half of the region show a variation of about 1.2 magnitudes each, while that of the third is about a magnitude. Variables whose changes are slight on this pair of plates, are well seen on others. There are many other regions of equal interest. No catalogue stars are contained in these regions, as even the brightest are too faint to appear in the Cape Photographic Durchmusterung.

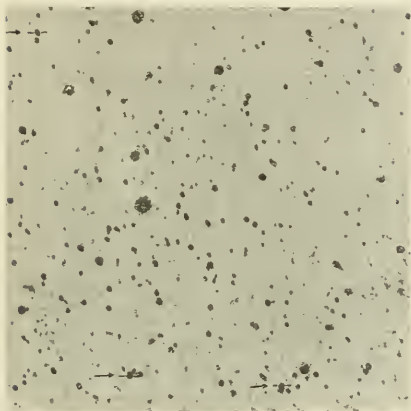


FIGURE 1.

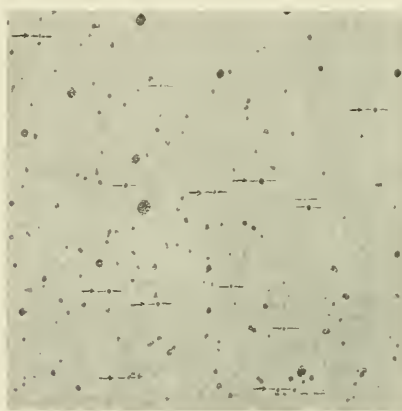


FIGURE 2.

The number of stars shown in the photographs, in the central portion of the region, is about thirteen to a square minute of arc, or 46.800 to a square degree. It is estimated that the number of stars photographed in the Small Magellanic Cloud and adjacent clusters is about 280,000, of which 910, or one in 308, is variable. In the surrounding region about 40,000 stars appear on the best negatives, of which 12, or only one in 3,300, have been found to be variable, although all have been examined with equal care. The region covered by the figures comprises 144 square minutes, and includes at least 1272 stars, of which 755 may be called conspicuous. It is very difficult to count the faint stars which cloud the background, on account of their closeness to one another, and the number is certainly underestimated. Few of the variables have been observed to become as faint as these stars. The figures cover about one thousandth of the entire region, which if displayed upon the same scale would occupy seven by eight and a half feet.

During the examination for variables, a star of about the thirteenth magnitude, whose position for 1900 is R. A. = $1^h 6^m 1^s$, Dec. = $-72^\circ 45'.5$, was found to have a large proper motion. No such motion has heretofore been detected in so faint a star. Measures of this object, with reference to three adjacent stars, were made on five plates, with the results given in Table II. The year, month, and day are

TABLE II.
PROPER MOTION.

Date.			t	x	O—C	y	O—C
y.	m.	d.	y.	"	"	"	"
1890	9	13	0.8	0.0	+0.4	0.0	-0.7
1898	10	10	8.9	+3.6	-0.8	+5.0	+0.9
1898	11	10	8.9	+4.9	+0.5	+4.5	+0.4
1904	8	17	14.7	+7.5	-0.4	+5.8	-0.8
1904	9	29	14.8	+8.2	+0.2	+6.6	0.0

given in the first column, and the time, t , following 1890.0, expressed in years and tenths, is given in the second column. The abscissas of the star referred to its position on the first plate, is given in the third column, and shows the motion in right ascension. The value of x is closely represented by the formula $x = -0''.9 + 0''.60 t$. The residual found by subtracting the value of x , computed by this formula, from the observed value is given in the fourth column. The observed value of y and the residual, assuming the relation $y = +0''.4 + 0''.42 t$, are given in the fifth and sixth columns. The average values of the residuals in the fourth and sixth columns are $\pm 0''.46$ and $\pm 0''.56$. The annual proper motion in right ascension is $+0''.60 = +0''.13$, in declination $+0''.42$, in a great circle $0''.73$.

EDWARD C. PICKERING.

APRIL 12, 1905.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 97.

BRUCE PHOTOGRAPHS OF PLANETS.

IN planning the Bruce 24-inch Telescope, it was expected that it might be used for the discovery of faint satellites. Accordingly, photographs were taken of several of the planets, and an examination of those of Saturn resulted in the discovery of the ninth satellite, Phoebe. In photographic, as well as in visual work, it is much easier to confirm an object whose position is known than to make the original discovery. A list is accordingly given in Table I of the plates, so far taken, which may prove useful in this way. The name of the planet; the number of the plate in Series A; the year, month, and day; the Julian Day and decimal following Greenwich Mean Noon, corresponding to the centre of the exposure; the duration of the exposure; and the right ascension and declination of the centre of the plate are given in the successive columns.

TABLE I.
LIST OF PLATES.

Object.	Plate A.	Date.			J. D.	Exp.	R. A. 1900.		Dec. 1900.
		y.	m.	d.			h.	m.	s.
Mercury . . .	2640	1897	8	14	4151.492	15	11	9	+ 6.5
"	2644	"	"	16	4153.488	25	11	17	+ 3.7
"	2649	"	"	17	4154.487	25	11	23	+ 3.2
"	2653	"	"	18	4155.491	25	11	24	+ 2.7
"	3505	1899	5	1	4776.913	8	1	4	+ 4.3
"	3506	"	"	1	" .918	3	1	4	+ 4.4
"	3510	"	"	2	4777.926	20	1	10	+ 4.5
"	3511	"	"	2	" .935	4	1	10	+ 4.5
"	3518	"	"	8	4783.907	17	1	24	+ 5.5
"	3520	"	"	9	4784.909	23	1	29	+ 5.5
"	3521	"	"	9	" .922	3	1	29	+ 5.5
"	3523	"	"	10	4785.912	28	1	32	+ 6.8

Object.	Plate A.	Date.			J. D.	Exp.	R. A. 1900.		Dec. 1900.
		y.	m.	d.			h.	m.	s.
Mars	2192	1896	12	28	3922.539	35	4	46	+25.1
"	2195	1897	1	5	3930.668	60	4	38	+25.1
Vesta	406	1894	3	23	2911.662	71	11	10	+17.5
"	461	"	"	27	2915.550	60	11	7	+17.5
"	6108	1902	8	20	5982.506	35	19	7	-26.4
"	6109	"	"	21	5983.517	90	19	8	-26.7
"	6116	"	"	22	5984.565	150	19	23	-25.6
"	6137	"	9	2	5995.633	120	19	7	-30.1
Jupiter . . .	22	1893	11	18	2786.694	17	3	36	+19.1
"	27	"	"	20	2788.655	17	3	34	+18.8
"	36	"	"	24	2792.648	15	3	33	+17.8
"	41	"	"	25	2793.577	10	3	41	+17.3
"	46	"	"	26	2794.596	14	3	30	+17.8
"	60	"	"	30	2798.639	60	3	27	+17.8
"	185	1894	1	23	2852.556	60	3	17	+17.3
"	191	"	"	25	2854.563	60	3	15	+17.0
"	215	"	2	2	2862.489	61	3	14	+17.0
"	2640	1897	8	14	4151.492	15	11	9	+6.5
"	3550	1899	5	29	4804.542	158	13	52	+10.2
"	3554	"	"	30	4805.577	180	13	53	-10.3
"	3556	"	"	31	4806.507	90	13	51	-9.9
"	3654	"	6	26	4832.534	120	13	54	-10.2
"	3655	"	"	26	" .589	30	13	54	-10.2
"	3657	"	"	27	4833.551	174	13	54	-10.3
"	3658	"	"	27	" .625	30	13	54	-10.3
"	3666	"	"	30	4836.538	124	13	55	-10.4
"	3667	"	"	30	" .595	30	13	53	-10.4
"	3669	"	7	1	4837.566	120	13	54	-10.0
"	3670	"	"	1	" .623	30	13	54	-10.0
Uranus . . .	557	1894	4	26	2945.684	60	14	50	-15.5
"	602	"	5	3	2952.616	57	14	50	-15.5
"	2650	1897	8	17	4154.544	60	15	26	-17.3
"	2651	"	"	"	" .593	60	15	26	-17.3
"	2654	"	"	18	4155.551	60	15	27	-17.4
"	3526	1899	5	16	4791.746	164	16	21	-21.3
"	3531	"	"	20	4795.862	123	16	18	-21.4
"	3630	"	6	12	4818.694	259	16	14	-20.8
"	3632	"	"	13	4819.681	240	16	11	-21.1
"	3634	"	"	14	4820.677	121	16	10	-20.8
"	3635	"	"	15	4821.774	180	16	10	-20.8
"	3690	"	7	7	4843.589	270	16	9	-22.3
Neptune . . .	7124	1905	1	9	6855.662	120	6	28	+22.3
"	7126	"	"	10	6856.648	120	6	28	+22.3
"	7181	"	"	24	6870.572	120	6	26	+22.3

The plates of Saturn are not given, since they are described in the Harvard Annals, Volume LIII. The faintest stars shown upon these plates may be estimated from the observations of Phoebe. This satellite appears on nearly all the good photographs in the region of Saturn taken with the Bruce Telescope, and having an exposure of more than an hour. It is barely visible with the Yerkes Telescope, which has an aperture of 40 inches, and attempts to see it with the Lick Telescope, aperture 36 inches, have so far failed. The computed limiting magnitudes corresponding to these apertures, are 16.8 and 17.0. Allowing for the loss of light, due to the absorption in large lenses, the magnitude of Phoebe may be assumed to be not far from 16.5. The faintest stars shown with the Bruce Telescope, with an exposure of one hour, may be assumed to be 17.0, and 17.5 with an exposure of two hours, if the images are small and perfectly circular. If the images are elongated, much brighter stars may fail to be shown. While a very slight fogging permits somewhat fainter stars to be seen, the limit is soon reached and a moderate darkening of the plate cuts off all very faint stars. For this and other reasons an increase in the exposure does not produce a corresponding increase in the number of stars photographed. In some cases, an exposure of one hour shows as faint stars as an exposure of five hours. We may therefore infer that should distant satellites brighter than the sixteenth magnitude be discovered revolving around Mars, Vesta, Jupiter, Saturn, Uranus, or Neptune we may expect to find them upon the plates enumerated in Table I, and material may thus be derived for determining the periods with great accuracy.

As soon as the orbits of the sixth and seventh satellites of Jupiter are known approximately these photographs should serve to correct the elements, especially the period, if the satellites can be found on them. As their estimated magnitudes are 14 and 16 there should be no difficulty in finding them, as soon as their approximate places are known.

It was at first thought by European astronomers that a mistake had been made and that the sixth satellite of Jupiter was an asteroid. It is curious that the writer when examining these very plates several years ago was tempted to make a similar mistake. An object was found on all the plates taken in June and July, 1899, which moved slowly, like Jupiter, and did not leave a trail. It appeared to come to its stationary point at nearly the same time as Jupiter, and therefore seemed to be at about the same distance. It was actually an asteroid near aphelion whose slow motion was due to its eccentricity. The number of asteroid trails found upon these plates is very large. No less than seven of them were marked upon Plate A 3550 by Dr. Stewart in 1899. It is difficult to identify

them since they are not near opposition, which is the only part of their orbit for which the Berlin Jahrbuch now gives their positions. Approximate ephemerides, from the first to the second stationary points, are much needed. As stated, *Annals* LIII. 99, a very faint object was found by Mrs. Fleming which closely resembled a new satellite of Saturn, but which afterwards proved to be an asteroid.

EDWARD C. PICKERING.

APRIL 20, 1905.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 98.

STARS HAVING PECULIAR SPECTRA.

AN examination of the photographs of the Henry Draper Memorial has led to the discovery by Mrs. Fleming of a number of variable stars and other objects having peculiar spectra. A list of these, together with three additional stars having bright hydrogen lines to which attention was called by Mr. Edward S. King, is given in Table I. The constellation and number in the Durchmusterung are given in the

TABLE I.
PECULIAR SPECTRA.

Constellation.	DM. No.	R. A. 1900.	Dec. 1900.	Magn.	Spectrum.	Description.
		<i>h.</i> <i>m.</i>	<i>°</i> <i>'</i>			
Cassiopeia	...	0 4.3	+51 0	..	Md.	Variable. II 1166.
Cepheus	...	0 7.6	+71 32	..	Pec.	Bright lines and bands.
Cassiopeia	+49° 41	0 12.2	+49 44	..	Na.	Variable. II 1167.
Phoenix	-48° 313	1 10.2	-48 47	9.4	Pec.	Dark bands.
Cassiopeia	...	1 50.2	+62 49	..	Pec.	Gaseous Nebula.
Eridanus	-57° 400	2 2.2	-57 37	..	Md.	Variable. II 1168.
Horologium	-43 1198	3 46.7	-43 50	8.5	Pec.	Dark bands.
Camelopardalus	+58° 804	4 57.4	+58 50	6.0	B Pec.	He, Hδ, Hγ, and Hβ, bright.
Puppis	-22° 1874	7 22.8	-22 53	6.0	B Pec.	Hβ bright.
Cancer	...	9 2.2	+21 58	..	Pec.	Dark bands?
Hydra	-22° 2684	9 36.7	-23 8	5.0	B Pec.	Hβ bright.
Ursa Major	...	12 34.4	+59 2	..	Md.	Variable. II 1169.
Virgo	...	12 57.4	+ 5 43	..	..	Variable. II 1170.
Lupus	...	14 46.8	-46 12	..	..	Variable. II 1171.
Ophiuchus	-18° 4282	16 21.2	-18 14	5.2	B Pec.	He, Hδ, Hγ, Hβ, bright.
Draco	...	17 53.2	+64 9	..	Pec.	Dark bands.
Cygnus	...	19 57.8	+32 18	..	Pec.	Bright lines. Type V.
Cygnus	+46° 3133	20 56.4	+47 8	5.3	B Pec.	Hζ, Hε, Hδ, Hγ, Hβ bright.
Cygnus	...	21 28.7	+44 10	..	Pec.	Bright lines. Gaseous Neb.
Pegasus	+22° 4508	21 51.7	+22 24	..	Na.	Variable. II 1172.
Pegasus	+20° 5071	21 59.7	+20 34	8.7	Pec.	Dark bands.
Piscis Austrinus	-25° 16142	22 46.7	-25 49	..	Mc.	Variable. II 1173.

REMARKS.

- h. m.*
 0 4.3. 000451 = H 1166. An examination of this star on five chart plates, taken between November 23, 1898, and December 6, 1902, shows a variation of about 2.5 magnitudes. Estimates from these plates give the approximate limits, 9.0 to 11.5.
- 0 7.6. This object is N.G.C. 40. Five bright lines or bands appear in its spectrum, 3869, 4101, 4340, 4688, and 4861. The first band is broad, and apparently coincides with the band seen in certain gaseous nebulae. The second, third, and fifth lines are H δ , H γ , and H β . The fourth band, which is the strongest of all, has the position of the characteristic line in the spectra of the fifth type. The nebular lines near wave length 5000 are not seen. This object may therefore be intermediate between a nebula and a fifth type star.
- 0 12.2. 001249 = H 1167. An examination of this star on sixteen chart plates, taken between January 3, 1890, and December 19, 1902, shows a variation of about 1.5 magnitudes. Estimates from these plates give the approximate limits, 7.5 to 9.0. Spectrum already known as fourth type.
- 1 10.2. This spectrum is of the same type as C. DM. -47° 6614, described in Circular No. 76.
- 1 50.2. Assumed to be the following and southern of two faint and difficult objects, which also appears somewhat hazy. The spectrum consists of a bright band having wave length of about 5000. Therefore, this object has been assumed to be a gaseous nebula.
- 2 2.2. 020257 = H 1168. An examination of this star on six chart plates, taken between July 29, 1896, and September 1, 1903, shows a variation of about 2.5 magnitudes. Estimates from these plates give the approximate limits, 7.5 to 10.0.
- 3 46.7. Announced as Type IV, *Astron. Nach.* **138**, 175. The spectrum is of the same type as C. DM. -47° 6614, described in Circular No. 76. The broad, dark bands in these spectra have approximately the same wave lengths as the bands in stars of the fourth type, Class Nd, but the intensity of the light of the spectrum between each band increases towards the violet, while in the peculiar stars the light between each band is of uniform intensity throughout.
- 4 57.4. Fine bright lines superposed on broad, dark bands.
- 7 22.8. This spectrum was marked "Peculiar" on Plate C 15655, by Mr. Edward S. King. The line H β , and three faint lines whose approximate wave lengths are 4594, 4640, and 4727, are bright in this spectrum.
- 9 2.2. This object is very faint and difficult, but it appears to be of the same type as C. DM. -47° 6614, described in Circular No. 76.
- 9 36.7. H β narrow and bright superposed on broad, dark band.
- 12 34.4. 123459 = H 1169. An examination of this star on ten chart plates, taken between April 11, 1890, and April 7, 1905, shows a variation of more than 2.3 magnitudes. Estimates from these plates give the approximate limits, 9.7 to < 12.
- 12 57.4. 125705 = H 1170. Found from chart plates, while examining RT Virginis, which follows 11°, 0' 2" north. Four plates, taken between April 7, 1890, and May 7, 1898, show a variation of more than a magnitude. Estimates from these plates give the approximate limits, 10.3 to 11.5.
- 14 46.8. 144646 = H 1171. This star follows S Lupi 0° 4', south 12", and on most of the plates is a difficult object, especially when S Lupi is bright. It has been observed on 140 chart plates, taken between June 13, 1889, and September 4, 1901. Measures of these plates give the brightest and faintest magnitudes, 10.44 and 12.81.
- 16 21.2. This star is χ Ophiuchi. Attention was called to the peculiarity of this spectrum, "Bright line, and doubling of lines," on Plate C 15590, by Mr. Edward S. King. The presence of the bright line H β in this spectrum was announced in the *Astron. Nach.* **126**, 163. The photograph taken on March 14, 1905, shows H γ , H ϵ , H δ , H γ , and H β as fine bright lines superposed on strong dark bands. As in other spectra of this class, the bright hydrogen lines diminish progressively in intensity, those of shortest wave length being faintest.
- 17 53.2. This spectrum is of the same type as C. DM. -47° 6614, described in Circular No. 76.
- 20 56.4. This star is ρ^1 Cygni. Attention was called to the peculiarity of this spectrum, "Bright lines" on Plate C 15177, taken on November 15, 1904, by Mr. Edward S. King. This plate shows H γ , H ϵ , H δ , H γ , and H β as fine bright lines superposed on strong dark bands. These lines diminish in intensity corresponding to their relatively shorter wave length. Other fine bright lines at approximate wave lengths 3993, 4440, 4597, and 5009 are visible. Plate C 15203, taken on November 24, 1904, shows the bright H δ , H γ , and H β . The last two named lines are on the edge of shorter wave length of the dark lines H γ and H δ . This change seems to indicate a spectroscopic binary, one component having bright hydrogen lines.
- 21 28.7. This object is exceedingly faint.
- 21 51.7. An examination of this star on nine chart plates, taken between September 18, 1892, and October 27, 1904, shows a variation of more than a magnitude. Estimates from these plates gave the approximate limits, 8.1 to 9.4. The range from direct examination is certainly greater.
- 21 59.7. 215122 = H 1172. This spectrum is of the same type as C. DM. -47° 6614, described in Circular No. 76.
- 22 46.7. 224625 = H 1173. An examination of this star on twenty-five chart plates, taken between July 23, 1889, and October 3, 1901, shows a variation of about 0.8 of a magnitude.

first two columns. The approximate right ascension and declination for 1900 and the catalogue magnitude, except in the case of variable stars, are given in the third, fourth, and fifth columns. The class of spectrum and a brief description of the object are given in the sixth and seventh columns. The designations for stars north of declination -23° are taken from the Bonn Durchmusterung, for stars between declination -23° and -52° the Cordoba Durchmusterung is used, and for stars south of declination -52° the Cape Photographic Durchmusterung is used. Each of the new variables has been confirmed independently by a second observer. Additional information regarding these objects will be found in the remarks following the table. In the case of new variable stars, the right ascension is followed by the designation described in the Annals XLVIII, 93, which gives the approximate position and also the designation described in the Annals LIII, No. VII, which indicates the number in the series of variables found at Harvard. This number is also given in the table for convenience of future reference.

SPECTRA OF KNOWN VARIABLES.

The spectra of a number of known variables have also been determined from these photographs and are given in Table II. The first column contains the designation, and the second, the name of the variable. The third column gives the class of spectrum.

TABLE II.

SPECTRA OF KNOWN VARIABLES.

Desig.	Name.	Spectrum.	Desig.	Name.	Spectrum.	Desig.	Name.	Spectrum.
004958	W Cassiopeiae	Mb 5 c	054974	V Camelop.	Md 6	093178	Y Draconis	Md 6
015912	S Arietis	Md 4	055353	Z Aurigae	Mb	093934	R Leonis Min.	Md 9
031401	X Ceti	Mb	060450	X Aurigae	Md 3	104814	U Leonis	Md 7
032043	Y Persei	Na	064030	X Geminorum	Md 5	122532	T Canis Venat.	Mc.
043065	T Camelop.	Pec.	071713	V Geminorum	Md 5	175519	RY Herculis	Md ?
043274	X Camelop.	Md 6	073508	U Canis Min.	Mb	195202	RR Aquilae	Md
045307	R Orionis	Md ?	083350	- Ursae Major	Md	203816	S Delphini	Mc.

REMARKS.

004958. The spectrum of this star is given as N? in the Provisional Catalogue of Variable Stars, Annals XLVIII, No. III. Plate I 32618, taken on February 10, 1905, shows the spectrum of this star as Class Mb5c.

032043. The spectrum of this star is given as N? in the Provisional Catalogue of Variable Stars, Annals XLVIII, No. III. Plate I 32279, taken on November 7, 1904, shows the spectrum as Na, or similar to U Hydraz.

043065. The spectrum of this star is given as N in the Provisional Catalogue of Variable Stars, Annals XLVIII, No. III. Plate 132380, taken on December 1, 1904, shows that this spectrum is Peculiar. The lines $H\beta$ and a wide band about 4670 are present and dark, and the faint spectrum extends to He. On a poor plate this might readily be mistaken for a fourth type spectrum.

This image was carefully compared with a chart plate, 14129, taken on December 3, 1895.

195202. The spectrum of this star is given as Md? in the Provisional Catalogue of Variable Stars, Annals XLVIII, No. III. Plate B 22023, taken on October 10, 1898, shows that the spectrum is Md, having the lines He, $H\delta$, and $H\gamma$ bright, and resembling R Hydrae.

In many, if not all, of the variable stars of long period the bright hydrogen lines are not present when the star is faint. Accordingly, stars whose spectra are given as Mb, or Me in Table II, may later be found to have spectra of Class Md.

EDWARD C. PICKERING.

MAY 5, 1905.

HARVARD COLLEGE OBSERVATORY.

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CIRCULAR No. 99.

A PROBABLE NEW STAR, RS OPHIUCHI.

New stars can be distinguished from variables, in many cases, only by their spectra. The usual life of a new star is marked by its sudden appearance, where no star is previously known to have existed, and a gradual fading away during which it changes into a gaseous nebula. But the New Star of 1866, T Coronae, had already been recorded in the Bonn Durchmusterung, and is still visible as a star of the tenth magnitude. The New Star of 1901, Nova Persei, No. 2, was shown by earlier photographs to be a very faint variable, and the New Star of 1600, P Cygni, is still well seen as a star of the fifth magnitude, which does not now vary perceptibly. Moreover, η Carinae appears as a star of the seventh magnitude, after undergoing great and irregular changes in light during nearly a century.

From the Draper Memorial photographs it has been shown that the spectra of variables of long period are generally either of the third type, Class Md, in which one or more of the hydrogen lines, H δ , H γ , and H β , but not H ϵ , are bright, or of the fourth type, Class N. The spectra of the bright novae are very complex, but when faint even at maximum only a few bright lines are visible. These consist of the hydrogen lines H ϵ , H δ , H γ , and H β , and one or more bright lines between 4600 and 4700, which appear to coincide with the characteristic bands of spectra of the fifth type. Nova Centauri, however, had a wholly different spectrum.

In Circular No. 76, Mrs. Fleming pointed out that the spectrum of the star 174406, RS Ophiuchi, on July 15, 1898, was of the third type in which the hydrogen lines H ζ , H ϵ , H δ , H γ , and H β were bright, and also two lines which appear to coincide with the bright bands 4656 and 4691, in γ Velorum. As these bands have a width of several units and are sometimes brighter on one edge than on the other, it is impossible to give their exact wavelengths. This spectrum, therefore, closely resembles that of Nova Sagittarii and Nova Geminorum. A photograph taken on the preceding day, July 14, confirms the presence of these lines, while a photograph taken on August 28, 1894, showed that at that time the spectrum was of Class K, with no evidence of bright lines. Mrs. Fleming's record in 1899, after examining the first of these, was "Nova?"

TABLE I.
ANNUAL RESULTS.

Year.	No.	Mean.	A. D.	Year.	No.	Mean.	A. D.
1888	1	10.86	..	1898	11	... .	..
1890	2	10.88	.02	1899	14	10.56	.26
1891	2	10.78	.02	1900	24	9.67	.32
1892	4	10.65	.11	1901	34	9.82	.23
1893	7	10.26	.10	1902	41	9.97	.18
1894	6	10.46	.28	1903	26	10.28	.20
1895	6	10.36	.07	1904	51	10.24	.18
1896	9	10.21	.18	1905	4	9.78	.26
1897	11	10.50	.23				

Miss Cannon, from an examination of the light curve, called attention to the remarkable increase in the light of this star which took place in 1898. The star has been photographed at this Observatory each year since 1888, except in 1889. The year, number of photographs, mean magnitude, and average deviation of the separate results are given in Table I. The individual results in 1898 are given in Table II.

TABLE II.
RESULTS FOR 1898.

Date.	Magn.	Date.	Magn.
April 2	10.70	August 15	9.27
May 27	10.76	" 20	9.32
" 31	10.81	September 7	10.00
June 30	7.69	" 29	10.28
July 14	8.26	October 8	10.81
" 15	8.22		

It will be seen from these tables that the star appears to have had the magnitude 10.9, before 1891, then increasing gradually about half a magnitude to 10.4 and retaining this brightness during 1893 to 1897. In 1898, it was at first faint, magnitude 10.8, until May 31. A month later, on June 30, it was more than three magnitudes brighter, or 7.7, and decreased regularly about a magnitude a month

until October 8, when it was again magnitude 10.8. The following year, 1899, it remained faint, 10.6, but in 1900 it attained the magnitude 9.3 in April, diminishing to 10.0 in September. This change accounts for the large average deviation in the fourth column. Since then, the variations have been slight. An examination of several good chart plates, shows only one star in this position.

Nearly all of the objects mentioned above are shown on the Harvard Map of the Sky. RS Ophiuchi appears on Plate 31, [118, 58]; T Coronae, on Plate 18, [113, 59]; Nova Persei, No. 2, on Plate 12, [131, 185]; P Cygni, on Plate 20, [72, 149]; η Carinae, on Plate 50, [153, 64]; γ Velorum, on Plate 49, [155, 168]; and Nova Geminorum, on Plate 13, [39, 107].

Both the spectrum and the light curves therefore indicate that this object should be regarded as a Nova, rather than a variable star, and its proper designation will be Nova Ophiuchi, No. 3, the new stars of 1604 and 1848 having also appeared in the same constellation.

EDWARD C. PICKERING.

MAY 15, 1905.

HARVARD COLLEGE OBSERVATORY.

CIRCULAR No. 100.

VARIABLE STARS IN THE CLUSTERS MESSIER 3 AND MESSIER 5.

A DISCUSSION of the variable stars in the Cluster ω Centauri is given in Volume 38 of the Harvard Annals. A continuation of this work is now in progress, and Professor Bailey has given below some of the conclusions at which he has arrived.

The determination of the elements of the Variable Stars in the clusters, Messier 3, N.G.C. 5272, and Messier 5, N.G.C. 5904, except for some minor corrections, is now completed. The results obtained are in harmony with the preliminary announcements which have already been made in the H. C. O. Circulars, Nos. 2, 18, 24, 33, and 52, and in the Astrophysical Journal, 10, 255.

In the ratio of the number of variables found to the whole number of stars examined, these clusters are the most remarkable yet discovered, the proportion being one to seven for Messier 3, and one to eleven for Messier 5. The more complete study of these clusters will only slightly, if at all, modify the figures already published.

In such small and closely-packed clusters many of the stars are measured only with difficulty. Of the 129 stars in Messier 3, whose variability has been verified by measurements on many plates, definite periods have been determined for 109. The number of periods found for the variables in Messier 5 is 65, out of 87 stars whose variability has been established by the measurements. In both these clusters, the similarity among the variables is remarkable. Only two stars appear to be exceptions to this rule, Nos. 42 and 50, in Messier 5, whose periods are $25^d.74$, and $105^d.6$, respectively. All the other variables of both clusters, whose periods are known, 63 in the case of Messier 5, and 109, in Messier 3, have periods varying little from 13^h . All, or nearly all, of them belong to Class IV, Subclass a, Harvard Annals, 38, 132. The mean period of all the variables in Messier 3 is $0^d.542$, or $13^h 0^m$, and for Messier 5, omitting Nos. 42 and 50, $0^d.531$, or $12^h 45^m$. The greatest difference from the mean is $0^d.166$ for Messier 3, and $0^d.168$ for Messier 5, about 4^h in each case. There are few such large differences, however, the average deviation

from the mean period being $0^d.042$, or $1^h 0^m$ for Messier 3, and $0^d.051$, or $1^h 13^m$ for Messier 5. In Messier 3, there are 15 periods, and in Messier 5, 5 periods, which differ from the mean by less than $0^d.01$. All the variables are of about the same brightness, varying between the thirteenth and the sixteenth magnitudes, although the stars of Messier 3 are somewhat fainter than those of Messier 5.

The observations included in the present discussion cover a period of about twelve years in the case of Messier 5, and of about five years in the case of Messier 3. This involves an average of about 8,350 returns of maximum for the variables of Messier 5, and 3,300 for Messier 3. This furnishes so much data for the careful determination of the periods, that the latter are probably correct in most cases within a few tenths of a second.

In H. C. O. Circular No. 52, the rapidity of the increase of light for three variables in Messier 3, Nos. 11, 96, and 119, was discussed. No reason has been found for modifying the results given in this Circular. Many other variables, both in Messier 3 and Messier 5, have been found, in which the rapidity of the increase of light is nearly equal to that of the stars mentioned above, but no variable has been found in which the increase of light appears to be more rapid than that of Messier 3, No. 96.

In the Harvard Annals, 38, 182, the suggestion was made in the case of ω Centauri, No. 36, that the period perhaps underwent a secular variation in length. This suggestion appears to be confirmed by a considerable number of the variables in Messier 3, and Messier 5. This subject will be discussed more fully in a forthcoming volume of these Annals, in connection with the study of the above clusters.

EDWARD C. PICKERING.

MAY 9, 1905.

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